... LESSONS IN PHYSICAL SCIENCE FOR GRAMMAR SCHOOLS

AVERY – SINNOTT.

SHELDON AND COMPANY
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FIRST LESSONS

IN

PHYSICAL SCIENCE

FOR USE IN GRAMMAR SCHOOLS

BY

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AVERY'S PHYSICAL SCIENCE SERIES

FIRST LESSONS IN PHYSICAL SCIENCE.

FOR USE IN GRAMMAR SCHOOLS.

(By Dr. AVERY and Prof. SINNOTT.)

ELEMENTARY PHYSICS.

A SHORT COURSE FOR HIGH SCHOOLS.

SCHOOL PHYSICS.

FOR HIGH SCHOOLS AND ACADEMIES.

ELEMENTS OF CHEMISTRY.

COMPLETE CHEMISTRY.

"The Complete Chemistry" contains "The Elements of Chemistry," with an additional chapter on Hydrocarbons in Series, or Organic Chemistry. It can be used in the same class with "The Elements of Chemistry."

TYPOGRAPHY BY J. S. CUSHING & CO., NORWOOD, MASS.

PREFACE.

The purposes of this book are:—

1. To create an interest in physical science that shall lead to scientific habits of thought, and a desire for further scientific knowledge.

2. To teach fundamental facts and principles that may enable the pupil to solve many of the practical problems that he must meet in the schoolroom and in the greater world outside. It is believed by the authors that this knowledge will be of immediate help to the pupil, as in his study of geography, physiology, etc.

3. To furnish training in experimental work and methods, thus preparing for the laboratory work of the high school.

The special features of the book are:—

1. The experiments may be performed with very simple and inexpensive apparatus.

2. They are illustrative of fundamental principles.

3. They are interesting to the pupils because they are new to them.

4. While most of them are qualitative, and, therefore, better adapted to the abilities and uses of the pupils, enough of them are quantitative to furnish needed training in that line.

5. The lesson of each experiment or series of experiments has been definitely formulated, with the occasional exception of certain words for which blanks have been left, and which the pupil should be required to supply *from his own thought.* Ideas that are left vague, or "all in the air," are injurious rather than helpful in their effect upon habits of thought and study.

6. As aids to this desirable definiteness of ideas, thought-provoking questions accompany the experiments.

7. At the end of each section are additional questions that call for the application of the principles learned, and for reading in other books. These questions are intended by the authors as little more than suggestions to the teacher, who should supplement them by others of his own making.

8. The selection of subjects has been determined by their immediate disciplinary value, and by their utility in other lines of school work, and in the life of later years.

Method of using this book: — While it is believed that the book may be successfully used with *any good method,* the following suggestions may be helpful: —

1. Require each pupil to perform many of the experiments. The more of this work he does, the better for him. The best, *i.e.* the ideal, plan would be for each pupil to have a set of apparatus and a regularly assigned place at the laboratory table. In many schools this would be impossible, but much may be done at extemporized tables and with such equipment as the teacher and pupils make. Still, a wise liberality on the part of the school authorities is exceedingly desirable.

2. Require some of the pupils to perform some of the experiments before the class. This work should be as-

signed in advance by the teacher and carefully prepared by the pupil. The experimenter should make himself ready to answer questions asked by the teacher and the other pupils. When the pupils "wake up" to the possibilities of this exercise, the "quiz" will be found exceedingly interesting and instructive.

3. Require some of the experiments, or parts of them, to be performed before the class, and by individual pupils, from the teacher's dictation. This work should be followed by close questioning on the part of the teacher.

4. Some of the experiments should be performed before the class by the teacher, and followed by such questions and information as may be necessary to impress the lesson of each experiment upon the minds of the members of the class. Much depends upon an ability to "make the experiments work"; careful rehearsals in private are, therefore, recommended.

5. Each experiment, however performed, should be accompanied by the careful taking of notes by every pupil. Each pupil should have his notebook. These books should be of uniform size and style; they should be neatly kept, and systematically criticised with reference to accuracy of observation and inference, arrangement, and neatness of penmanship and drawing.

6. Each pupil should be required to take part in the preparation of apparatus, and encouraged to make pieces of his own. This will greatly increase the interest and value of the work.

The Teacher should —

1. Require the pupils to report the result of each experiment, and clearly to state the lesson that it teaches.

2. Be assured that each pupil has mastered the lesson

of each experiment, not merely as an individual fact, but as a principle that may be used in the explanation of the phenomena of everyday life. To this end he should prepare and ask many questions supplementary to those given in the book. Draw the pupil outside of the book, and keep him in constant touch with the world around him. Train him constantly to the habitual application of principles that he learns in the class, and thus enable him the better to think for himself.

3. Require each pupil to *memorize* the leading facts and principles taught. Do not leave any lesson indefinite in the mind of any pupil if it can be avoided.

4. Encourage pupils to read and talk about the topics suggested by the experiment or the recitation, thus helping them to a profitable use of books and friends. It is often profitable to assign special topics (as waterworks, electric railways, etc.) to be investigated by individual pupils, for subsequent report to the class.

5. Remember that these things can be well done only when the teacher himself is a persistent and careful student of the subject, and of his pupils. A suggestion of a book to this one, a new experiment to that one, a visit with the class to some manufacturing establishment this week, and some other instructive enterprise next week, will arouse interest, and probably enthusiasm. But the teacher will not, cannot, do these things unless he is devoted to science and loves his pupils.

6. Remember that "the mind of the child is not a barn in which are to be stored the intellectual harvests of past generations. It is a field that is to be cultivated so that it may yield, year after year, crops of its own."

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CHAPTER I.

MATTER.

I. WHAT IS MATTER?

The best way to get a conclusive answer, is to ask the question of Nature directly, *i.e.* to make an experiment.

THE QUESTION AND THE ANSWER.

Experiment 1. — Provide a wide-mouthed bottle and a cork or a rubber stopper that fits it closely. The stopper should have two holes. Into one of the holes push the tube of a small funnel. Into the other hole push a lead pencil or other rod that will close it tightly. Snugly close the mouth of the bottle with the stopper.

FIG. 1.

What is in the bottle?

Pour water into the funnel.

Explain what happens.

Remove the pencil from the stopper.

Explain what happens.
What does this experiment teach about air?

NOTE. — Whenever, in this book, you are directed to use a cork, remember that a rubber stopper is preferable.

Experiment 2. — Substitute a short piece of glass tubing for the lead pencil used in Experiment 1. To the outer end of this tube, connect a piece of snugly fitting rubber tubing about 18 inches long. Fill a small wide-mouthed bottle with water; cover its mouth with a piece of paper; invert it without allowing any of the water to run out, and stand it in a shallow pan of water. Remove the paper, and hold the free end of the rubber tubing under the mouth of the bottle, taking care not to let any air enter the bottle. Pour water into the funnel of the other bottle.

FIG. 2.

What happens in the inverted bottle? Why?

Why does not water stay in the inverted bottle when air goes in?

What does this experiment teach about air?

Is the same thing true of water?

Anything that occupies space or takes up room is matter.

What term will, therefore, apply to both air and water?

Name some other forms of matter, and think out some other experiment to show that matter takes up room.

Determine which of the following are forms of matter: house, shadow of a house, steam, sound, illuminating gas, light.

The extent of space that a body occupies is its volume.
Any particular kind of matter is a substance.
Any definite portion of matter is a body.

Is matter a substance?

Is a substance matter?

Determine which of the following terms represent volumes, which represent substances, and which represent bodies: steel, a steel pen, a quart, a cubic yard, gold, a brick.

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2. DIVISIONS OF MATTER.

If we should take a small particle of water and divide and subdivide it until we obtain a particle so small that if we divide it again it will not be water, we should have what is called a *molecule* of water.

The smallest particle of matter that can exist by itself is called a molecule.

All matter is composed of these tiny particles separated from each other by extremely small spaces.

The particles that make up molecules are called atoms.

---

3. PROPERTIES OF MATTER.

INDESTRUCTIBILITY.

Experiment 3. — Put a lump of fresh lime about half the size of your fist into a pitcher and upon it pour a tumblerful of water. When the lime has crumbled, fill the pitcher with water and stir the contents thoroughly. Let the milky mixture stand until it settles and then pour off the clear liquid, which is "lime-water."

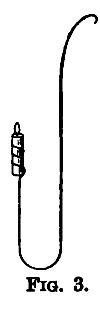


FIG. 3.

Put a little of the lime-water into a wide-mouthed bottle and shake it. See if there is any change in the appearance of the lime-

water. Mount a small candle on a J-shaped wire. Light the candle and lower it into the bottle. After it has burned for a minute or so, remove the candle and examine the contents of the bottle.

Do you detect anything in the bottle that was not there before?

Hold the palm of your hand over the mouth of the bottle and shake the contents.

What change do you notice in the appearance of the lime-water?

How do you account for the change?

Invert a cool, clear tumbler over the burning candle for a few seconds.

What change do you notice within the tumbler?

Can you account for the change?

When a candle is burned, it disappears, but the matter of which it is composed is not destroyed; it is simply changed to other substances. One of the substances thus formed by the burning of the candle was invisible, but it turned the clear lime-water to a milky-looking liquid. The burning of the candle also yielded watery vapor. If we could collect all of the substances formed by the burning of the candle, we should find that they weighed even more than the candle did, for they would contain something that was not in the candle, something that was taken from the air.

All matter is indestructible.

Give other illustrations of the indestructibility of matter.

INERTIA.

Experiment 4. — Balance a visiting card in a horizontal position upon the end of a finger, and rest a small coin upon it and directly above the finger. Give the card a sharp, horizontal snap.

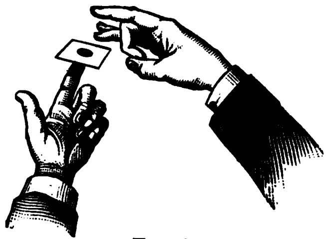


FIG. 4.

What tendency does the coin show?

All matter at rest has this tendency.

Did you ever stop a swiftly pitched base-ball?
What was the tendency of the moving ball?

All matter in motion has this tendency.

A ball may be rolled very far on the smooth, frozen surface of a pond.

Suppose there was nothing to stop it, how long would the ball continue to roll?
What tendency of matter is illustrated by this fact?

The tendency of a body when at rest to remain at rest, and when in motion to continue in motion, is called inertia.

POROSITY.

Experiment 5. — Fill a tumbler with gravel, and then see how much water you can pour into the tumbler.

Is gravel matter?
If it occupies space, how does it happen that water can be put into the tumbler when the tumbler is full of gravel?

Experiment 6. — Put a little water into a spoon and hold it over a flame until it disappears.

What has become of the water?
If air occupies space, how can water enter it?

We say that air is *porous;* there are spaces between its molecules.

All matter is porous.

Think of other illustrations of this.

DIVISIBILITY.

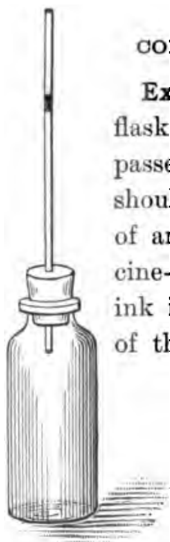
In what condition must water be before it can enter the spaces between the air particles?

We say that water has great *divisibility.*

Is the same thing true of other substances?

COMPRESSIBILITY AND ELASTICITY.

Experiment 7. — Tightly close the mouth of a flask or a bottle with a good cork through which passes a snugly fitting glass tube. The tube should be about 15 inches long and a quarter of an inch in diameter. By means of a medicine-dropper or a pen-filler, drop a little red ink into the tube. Gently breathe into the top of the tube.



What happens to the drop of ink?
As the ink moves down the tube, what happens to the air below?
When you stop breathing into the tube, what happens to the ink? Why?

FIG. 5.

Air may be compressed and is elastic.

All matter is compressible and elastic, to some extent.

4. CONDITIONS OF MATTER.

Experiment 8.—Half fill a tumbler with flour; half fill another tumbler with water; by the side of these, place a third tumbler containing only air. Push a pencil into

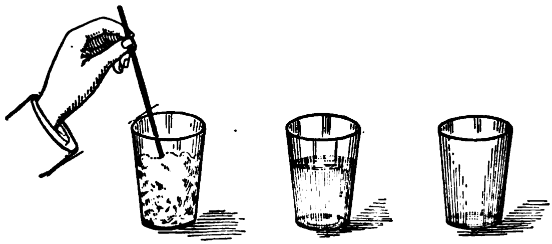


FIG. 6.

the flour and carefully remove it. Push the pencil into the water and carefully remove it.

What difference in the results do you notice?

Why this difference?

Examine the surface of the flour and that of the water, and state how they differ.

Can you find the surface of the air in the third tumbler? Why?

A body the particles of which are not free to move among themselves is a ______________.

A body the particles of which are free to move among themselves and that has a definite surface is a ______________.

A body the particles of which are free to move among themselves and that has no definite surface is a ______________.

In a gas, the particles tend to separate; in a liquid, they are loosely held together; in a solid, they are firmly held together. Matter always exists in one of these three forms.

Name some of the solids, liquids, and gases that you know.

Name a substance that may exist in each of these three conditions.

5. CHANGES THAT MAY TAKE PLACE IN MATTER.

Experiment 9. — Put a little salt in a test-tube; add some water and shake it.

What becomes of the salt?

Pour a few drops of the solution upon a piece of glass, and place it in the sun to dry, or gently warm it over a flame.

Put a small piece of zinc in a test-tube, and add a spoonful of hydrochloric acid.

What happens to the zinc?

Pour a few drops of the solution upon a piece of glass, and place it in the sun to dry, or gently warm it over a flame.

Compare the substance left upon each piece of glass with the corresponding substance that you dissolved.

In which case has a new substance resulted?

The change in the salt was a *physical change.*

The change in the zinc was a *chemical change.*

A chemical change is one that results in a ....

A physical change is one that does not ....

State the kind of change in each of the following: —

(*a*) The melting of ice is a .... change.
(*b*) The burning of a match is a .... change.
(*c*) The freezing of water is a .... change.
(*d*) The rusting of iron is a .... change.
(*e*) The dissolving of sugar is a .... change.

6. HOW PARTICLES OF MATTER ARE HELD TOGETHER.

Experiment 10. — Press a piece of soft beeswax or chewing-gum against the wall, and leave it there.

Why does it not fall?

Call the force that holds the wax against the wall *adhesion.*

How do the particles of wax compare in kind with the particles of the wall?

Adhcsion is the force that holds .... particles together.

The particles of the wax are held together by a force called *cohesion.*

Cohesion is the force that holds .... particles together.

What force causes the following: —

(*a*) Paint to stick to a house?
(*b*) A sponge to take up water?
(*c*) A stick to resist breaking?
(*d*) A postage stamp to stick to the envelope?
(*e*) A blotter to take up ink?
(*f*) A rubber band to spring back after being stretched?

Give other illustrations of these two kinds of force.

CRYSTALLIZATION.

Experiment 11. — Dissolve four tablespoonfuls of powdered alum in a tumblerful of hot water. Tie a tack to the end of a string and suspend it in the solution. Set the tumbler and its contents in a quiet place and let it

stand for twenty-four hours. Then notice the formation of *crystals* upon the string.

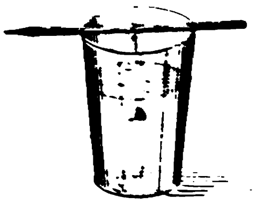


FIG. 7.

This phenomenon is known as *crystallization*.

What became of the alum when it was dissolved?

What force caused it to dissolve?

What force caused the alum molecules to come together again?

Give a reason for your last answer.

CAPILLARITY.

Experiment 12. — Place the end of a very slender glass tube in a tumbler of water colored with red ink, and notice the levels of the liquid inside and outside the tube.

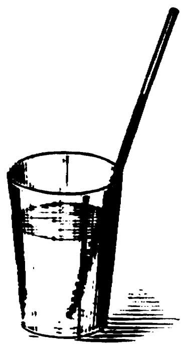


FIG. 8.

What force causes the water to rise in the tube above the level of the water in the tumbler?

This phenomenon is known as *capillarity*.

ABSORPTION.

Experiment 13. — Hold a piece of freshly burned charcoal under water. Observe what collects on the surface of the charcoal. See Fig. 9.

What do you think it is?

Where did it come from?

What made it come to the surface?

What force held it before it came to the surface?

We say that charcoal *absorbs* air and other gases within its pores.

To what force is absorption due?

FIG. 9.

Experiment 14. — Fold a circular piece of filter paper, or of blotting paper, along its diameter. Double the semicircle thus obtained upon itself to form a quadrant. Open the paper thus folded so that three thicknesses shall come upon one

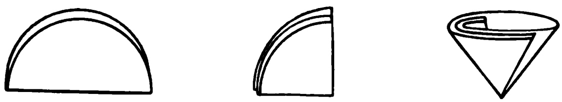


FIG. 10.

side and one thickness upon the other, and fit it into a glass funnel. Finely pulverize a piece of freshly burned charcoal about the size of a hen's egg. Put the powdered charcoal upon the paper in the funnel, thus forming a *filter*. Pour two or three spoonfuls of brown vinegar upon the charcoal and receive what passes through the filter in some convenient vessel. It is better to provide an independent support for the funnel; if the latter rests directly upon the bottle, put a match-stick or other small object between the fun-

FIG. 11.

nel and the neck of the bottle, so that air can easily escape from the bottle. Compare the color of the filtered vinegar with that of the unfiltered vinegar.

How do you account for the difference of color?

Can you think of any other substance that may be used as a filter?

What property of the charcoal makes it valuable as a filter?

QUESTIONS FOR THOUGHT AND READING.

1. What force is overcome when a nail is driven into wood? Why is it more difficult to drive it into hard than into soft wood?

2. A bouquet of hyacinths will fill a room with their odor. To what property of matter is this fact due?

3. What properties of air are illustrated by the pop-gun?

4. How does it happen that the flame of a kerosene lamp may be so far away from the oil in the lamp?

5. How may muddy water be made clear?

6. Why do doors sometimes "stick" in damp weather?

7. Logs that have been in water for a long time sometimes sink. How can you explain this?

8. What becomes of a solid when it is dissolved in a liquid?

9. In what respects are air and water alike? In what respects are they different?

10. How can you get solid salt from salt water?

11. Do you think that the air at the seashore has any salt in it? Why?

12. Why is spring water so clear?

CHAPTER II.

MECHANICS.

1. FORCE AND MOTION.

Motion is change of position.

Force is that which moves or stops a body or tends to do so.

Give an illustration of motion produced by force.

Give an illustration of motion stopped by force.

Can you think of any motion that is not produced by force?

Can you think of any way to stop a motion without using force?

Experiment 15. — Snap a marble lengthwise of the table. Snap it crosswise.

Why does the marble move in different directions?

Force and motion have direction.

The motions of matter give rise to *energy.*

Energy is the power of doing work.

Energy is as indestructible as matter. The two great, fundamental ideas of physical science are matter and energy.

INTENSITY AND VELOCITY.

Experiment 16. — Snap a marble gently. Snap it vigorously.

In what respect do the two motions differ? Why?

Force has intensity and motion has velocity.

Upon what does the velocity of a body depend?

Every motion or change of motion is in the direction of the force applied and is proportional to it.

How fast can you ride a bicycle?

In your answer you have named the two terms in which velocity is always reckoned, namely, ... and ....

The velocity of a body is the distance that it will move in a given unit of time, i.e. rate of motion.

Give other illustrations.

MEASUREMENT OF FORCE.

Experiment 17. — With a spring balance, weigh a two-quart pailful of sand.

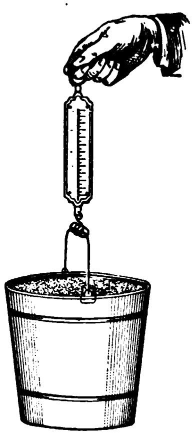


FIG. 12.

What is the force that pulls the sand down and stretches the spring?

In what units is the force measured?

Tie a string around the pail, fasten the balance to it, and pull the pail across the table.

In what units is the force measured?

Any force may be measured in units of weight, as the pound, ounce, gram, etc.

We say that steam exerts a pressure or force of a certain number of pounds to the square inch; that a pair of horses can pull so many tons; and that a man can lift a certain number of pounds.

MOMENTUM.

Experiment 18. — Move a one-pound weight 4 feet. Move a two-pound weight the same distance in the same time.

Which weight has the greater amount of motion?

How does the quantity of motion of the second weight compare with that of the first?

The quantity of motion that a moving body has is called its momentum.

The momentum of a moving body depends partly upon its ....

Experiment 19. — Move the one-pound weight with a velocity of 2 feet in 1 second. Move the same weight with a velocity of 4 feet in 1 second.

In which case is the momentum the greater?

The momentum of a moving body also depends upon its ....

How may a light body be given a momentum equal to that of a heavy body? Give an illustration.

How may a slowly moving body be given a momentum equal to that of a rapidly moving body? Illustrate.

LAW OF MOTION.

In what kind of a line does a ball move as it rolls upon smooth ice?

A moving body will continue to move in a .... line unless it is acted upon by some outside force.

Why is a rapidly moving wagon likely to tip over in turning a corner?

Can you throw a ball in a straight, horizontal line? Why?

In what kind of a line does the ball move when you try to do so?

Such motion is called ***curvilinear motion.***

Can curvilinear motion be produced by a single force?

How many forces does it take to produce curvilinear motion?

In what direction must a bullet be shot so that its motion shall be in a straight line, *i.e. rectilinear?*

What two forces act upon the bullet?

In what direction does each force act?

Why will the motion of the bullet be curvilinear when shot in any other direction?

How must a bullet be shot so that the effect of the two forces that act upon it may be found by subtraction?

How must it be shot so that the effect may be found by addition?

RESULTANT MOTION.

Experiment 20. — Swing two croquet mallets in directions that are at right angles to each other, and so as to hit a croquet ball at the same instant; or, in similar manner, snap, with one of the fingers of each hand, a light rubber ball suspended by a long thread. Observe the direction in which the ball moves.

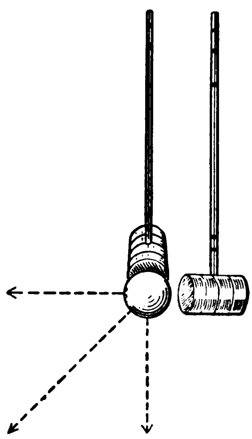


FIG. 13.

How many forces acted on the ball?

Did the ball move in the direction of either of the forces that acted upon it?

If a ball is rolled off the end of a table, in what kind of a line will it move after leaving the table?

To what two forces is this motion due?

Motion produced by the joint action of two or more forces is called resultant motion.

A man rows a boat at the rate of 4 miles an hour across a stream that is 4 miles wide, and that runs at the rate of 3 miles an hour. He makes no attempt to resist the current, but constantly heads his boat directly toward the opposite bank.

How long will it take him to cross the stream?
Where will he land?
Represent this resultant motion by a diagram.

The line that represents the resultant motion is the hypotenuse of a right-angled triangle.

Can you determine its length?
What would be the resultant motion if he should row one hour down the stream?
What if he should row one hour up the stream?
Give some other illustration of resultant motion.

QUESTIONS FOR THOUGHT AND READING.

1. Why is it more dangerous to fall from a rapidly moving bicycle than from one that is moving slowly?

2. One boy gives a quick pull, or jerk, to a sled upon which another boy is standing. What happens? Why?

3. A slowly moving freight car strikes with great force against a car at rest. Why?

4. Why does a sled move faster and faster as it goes down hill? Why will it keep on going after reaching the bottom of the hill?

5. When a street car suddenly stops what happens to the passengers? Why?

6. Two trains on parallel tracks are going in opposite directions. Each train is $\frac{1}{8}$ of a mile long, and has a velocity of 20 miles an hour. How long will it take the engine of one train to pass the other train?

2. GRAVITY.

DIRECTION IN WHICH GRAVITY ACTS.

Experiment 21. — Drop a stone and notice the direction in which it moves.

We have learned that all motion is the result of a _____.

What does the direction of the motion of the stone tell us?

What force produces the motion in this case?

In what direction does that force act?

Upon what other bodies does it act?

Experiment 22. — Suspend a stone or other heavy body by a string, and call the apparatus a *plumb-line.*

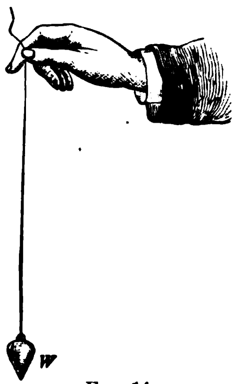


FIG. 14.

What force stretches the string?

What does the direction of the string tell us?

Toward what point in the earth does the plumb-line point?

Are plumb-lines parallel to each other?

The force that tends to draw all bodies on the earth toward the center of the earth is called gravity.

WEIGHT.

Experiment 23. — Hold a brick or a stone in the hand and observe the direction in which it presses.

To what is this pressure due?

Weight is the downward pressure caused by gravity.

Has a balloon weight?

Is weight a property of some bodies or of all bodies?

CENTER OF GRAVITY.

Experiment 24. — Bore a quarter-inch hole in each corner of a triangular piece of board. Cut the head from a wire nail, and drive the nail into some vertical support. Hang the board by one corner upon the nail, as shown in the figure. From the nail, suspend a plumb-line in front of the board, and mark the direction of the line upon the board. Then similarly support the board from each of the other holes, and mark vertical lines on the board in the same way. The three lines should cross at a common point, *G*. Bore a small hole at *G*, and thereby hang the board upon the nail. Turn the board into different positions and see if it balances in each.

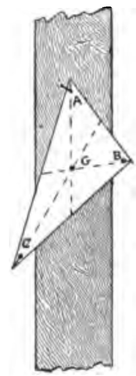


FIG. 15.

How must the weight of the part of the board that is at the right of the nail compare with the weight of the part at the left of the nail?

A body thus balanced in a state of rest is said to be in *equilibrium*.

Remove the board from the nail and place it upon the end of your upright fore-finger, with *G* immediately over the finger-tip.

Does it balance in that position?

The nail passes through the *center of gravity*. This point is also called the center of mass.

The center of gravity of a body is the middle point of the body with reference to its weight.

Is the center of gravity of a body necessarily at the middle point of the body?

Give a reason for your answer.

Give an illustration.

The straight line passing through the center of gravity of a body toward the center of the earth is called the ***line of direction*** for that body. If the body falls freely, its center of gravity will follow the line of direction.

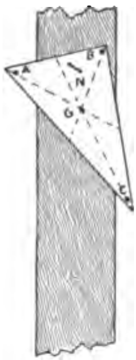


FIG. 16.

CONDITION OF SUPPORT.

In Experiment 24, where was the point of support with reference to the line of direction?

Experiment 25. — Bore another hole in the triangular board, avoiding the lines marked on it. Using this hole, support the board from the nail, and let it come to rest.

In this case, where is the point of support with reference to the line of direction?

A body supported at a single point will rest in equilibrium when the line of direction passes through ....

STABILITY.

Experiment 26. — Stand a crayon-box on end. (See Fig. 17.) Call the end on which it rests its *base.*

Where does the line of direction pass with reference to the base?

Tip the box over on edge. (See Fig. 18.)

When the box begins to fall, where is the line of direction with reference to the base?

When the line of direction falls .... the base, the body stands; when the line of direction falls .... the base, the body falls.

Illustrate this statement.

When you overturned the box, did you necessarily raise its center of gravity?

In what kind of a line did the center of gravity move?

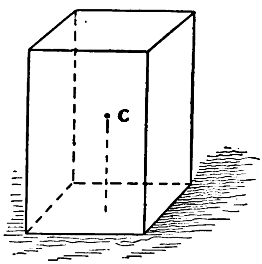


FIG. 17.

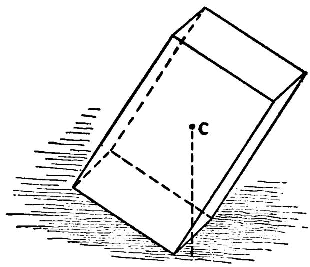


FIG. 18.

Experiment 27. — Stand the triangular piece of board on edge, and tip it over. Then lay it flat on the table, and tip it over.

In which position is the board the more stable?

In which case was the center of gravity lifted the greater distance?

Will a body be more stable when its base is broad and its center of gravity is low, or when its base is small and its center of gravity is high? Why?

Illustrate your answer, using a brick.

A body resting on its base is most stable when its center of gravity is as .... as possible, and its base is as .... as possible.

Why will a load of hay tip over more easily than a load of stone of the same weight?

Give examples of some bodies that are very stable.

Give examples of some bodies that are very unstable.

Place a cube, a sphere, and a cylinder resting on its side, on the top of a table:—

Which has a surface for its base?

Which has a line for its base?

Which has a point for its base?

Why is a cone standing on its circular bottom much more stable than it is when lying on its side?

What is the base of the cone when it is lying on its side?

Why is a glass ball resting on the marble top of a table very unstable?

What is the base of a chair standing on the floor?

QUESTIONS FOR THOUGHT AND READING.

1. Will a bag of sand in a balloon 5 miles high weigh more or less than at the sea level? Why?

2. If a person rides a bicycle, he must keep the line of direction in what position?

3. Is the velocity of a falling body constant or variable? Why?

4. What is the real force that causes a water-wheel to turn?

5. Where is the center of gravity for a wagon tire?

6. Why is a boat more likely to tip over when persons are standing up in it than when they are sitting down?

7. When a ball rests upon a level surface, where does the line of direction pass? Show this by a diagram. Show what happens when the surface is inclined, and explain why a ball rolls down hill.

3. THE PENDULUM.

WHY THE PENDULUM MOVES.

Experiment 28.— Suspend a bullet by a thread so that the distance from the fixed support to the middle of the bullet is 16 inches. Pull this pendulum to one side and let it go.

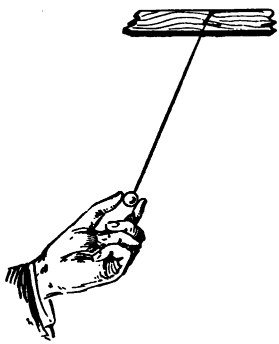


FIG. 19.

What force causes the bullet to move downward?

What causes it to move upward after it has reached its lowest possible point?

The motion of a pendulum is due to the force of.......... and to..........

How long will the pendulum continue to swing backward and forward, *i.e. to oscillate?*

Can you tell what makes it finally come to rest?

RATE OF OSCILLATION.

Experiment 29.— Swing the pendulum through an arc of about 5 inches, and count the trips from one end of the arc to the other (*i.e.* the oscillations) that it makes in 30 seconds. Then swing the pendulum through an arc of about 10 inches, and count the oscillations that it makes in 30 seconds.

How do the two numbers compare?

Repeat the test several times to be sure that there is no mistake about it.

The number of oscillations that a given pendulum makes in a given time is independent of the length of the arc through which it swings.

Experiment 30.— Using a heavier weight, make a pendulum of the same length as that used in Experiment 28. Swing it as before, and count the oscillations that it makes in 30 seconds. Repeat the work several times, to be sure of your result.

The number of oscillations that a given pendulum makes in a given time is independent of the .... of the pendulum.

Experiment 31. — Make a pendulum similar to the one used in Experiment 28, but 25 inches long. Set the two pendulums swinging at the same instant.

Which oscillates the more rapidly, the long one or the short one?

Count the oscillations that each makes in 60 seconds; divide the smaller number by the greater. Take the square roots of the lengths of the two pendulums ($\sqrt{16} = 4$ and $\sqrt{25} = 5$). Divide the smaller root by the larger. The two quotients should be equal.

With pendulums of different lengths, the numbers of oscillation are inversely proportional to the square roots of the .... of the pendulums.

Why is a pendulum of use in measuring time?
How can you make a pendulum clock gain or lose time?
Why does a clock need winding up?

THE SECONDS PENDULUM.

Experiment 32. — Lengthen the thread of one of the pendulums until the pendulum may be made to oscillate just 60 times a minute.

What is the length of a seconds pendulum?

QUESTIONS FOR THOUGHT AND READING.

1. If a pendulum clock gains time, how can it be "regulated"?

2. If two pendulums are respectively 25 and 49 inches long, how much faster will one vibrate than the other?

3. What is the length of a pendulum that oscillates once in two seconds?

4. A pendulum clock loses time. What is the trouble with it?

5. Why must a pendulum clock be wound up periodically?

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4. SOME SIMPLE MACHINES.

THE LEVER.

Experiment 33. — Rest a ruler upon a sharp edge, as that of a triangular block. Place a weight upon one end

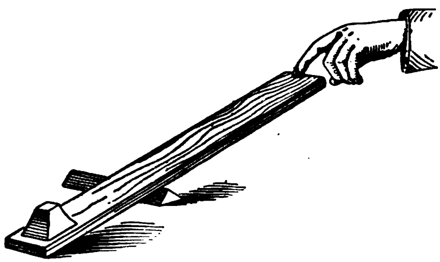

FIG. 20.

of the ruler, and lift it by pressing down upon the other end.

A ruler or other bar used in this way is called a *lever*. The sharp edge upon which the lever rests is called

the *fulcrum.* The force exerted by the hand is called the *power.* The thing thus lifted or supported is called the *load* or the *weight.* The distance from the fulcrum to the power is called the *power arm* of the lever ; that from the fulcrum to the weight is called the *weight arm.*

Experiment 34. — Prepare a straight piece of dry pine wood, 25 inches long, about 1 inch wide, and $\frac{1}{4}$ of an inch thick. Pass a part of a knitting needle at right angles through this ruler, about $\frac{1}{4}$ of an inch from one edge and

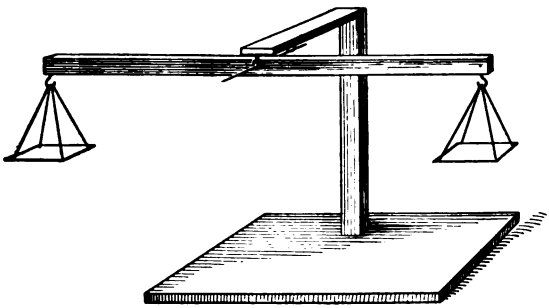

FIG. 21.

exactly $12\frac{1}{2}$ inches from each end. The needle should project equally from each side of the ruler. Insert two small screw-hooks of equal weight in the lower edge of the ruler, each exactly 12 inches from its middle. Support the ruler by resting the needle in two screw-eyes, as shown in Fig. 21. Make the ruler hang horizontal by whittling away a little from one end, or by adding putty or other material to the other end. Prepare two blocks of thin wood about 2 or $2\frac{1}{2}$ inches square and support them by knotted threads from the screw-hooks. Two

tin-can covers of equal size may be used instead. Make the apparatus balance by whittling one of the wooden blocks, or by adding putty, or, still better, bend a wire into U-shape, so that its two arms are about $\frac{1}{4}$ of an inch apart. Place this "rider" astride the ruler, and slide it into such a position that the apparatus balances. Its arms may be made to clasp the ruler just enough to hold it in position. Provide a number of ten-penny nails for weights; flattened bullets of the same size may be used if preferred. Place any convenient object on one of the scale-pans, and on the other scale-pan place enough weights to balance it. Because the apparatus balances, it is said to be in *equilibrium.*

A body is in equilibrium when all the forces acting upon it are balanced.

Give other examples of bodies in equilibrium.

Experiment 35. — Into the lower edge of the ruler used in Experiment 34, set additional screw-hooks at exactly

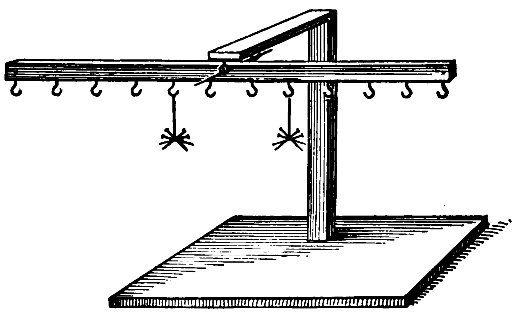

FIG. 22.

2, 4, 6, 8, and 10 inches from the middle point and on each side of it. Be sure that the apparatus balances as

before. Hang four ten-penny nails by a thread loop from each of the two hooks that are 4 inches from the fulcrum.

In what condition is the lever?

In similar manner, hang four nails 2 inches from the fulcrum, and two nails 4 inches from the fulcrum on the other side.

In what condition is the lever?

Remove the bunch of four nails, and find out where you must hang one nail to balance the two.

Make one nail balance two nails in as many ways as possible.

In each case of equilibrium, multiply the number of nails in each bunch by the number of inches its supporting hook is from the fulcrum, and see how the products compare; in other words, compare the product of the power into the power arm with the product of the weight into the weight arm.

With a lever, the power multiplied by the power arm equals the ____________.

A crowbar may be used as a lever.

Draw a straight line 6 inches long to represent the crowbar, and upon it place the letters, *P*, *W*, and *F*, to indicate the positions of the power, weight, and fulcrum of the lever shown in Fig. 23.

FIG. 23.

Can the fulcrum be at the end of the crowbar?

Draw other diagrams, showing the points *P*, *W*, and *F*, in as many different relative positions as possible.

Referring to Fig. 24, what is the power arm? What is the weight arm?

Does the law of equilibrium apply in such a case?

Can you think of any way in which to prove it?

Where have you ever used a lever?

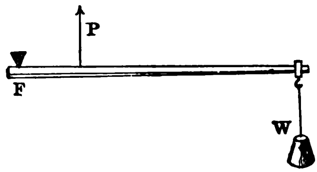

FIG. 24.

A balance is a ____________ having ____________ arms.

State how an unknown weight becomes known by the use of a balance.

Upon what law does the process depend?

Suppose that one arm of a balance is a little longer than the other, how could a dishonest dealer use it to his advantage?

How could the cheat be exposed?

THE PULLEY.

Experiment 36. — Procure a good spring-balance, and two good metal pulleys with wheels at least an inch in diameter. The pulleys may be made with empty wooden spools if necessary. Oil the pulleys so that the wheels turn easily. Fasten one to some solid support, and pass a stout cord over it. Weigh two bricks and tie one end of the pulley-cord around them. Fasten the other end of the cord to the hook of the spring-balance, lift the bricks by

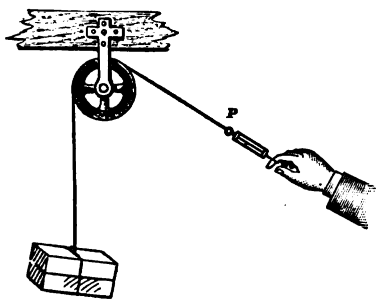

FIG. 25.

pulling on the balance, and hold them thus. A pulley thus used is called a *fixed* pulley.

Is the apparatus in equilibrium?

What is the weight of the bricks?

How many pounds does the balance indicate that you are lifting?

With a fixed pulley in equilibrium, how does the power compare with the weight?

Is the direction in which the power acts the same as that in which the weight acts?

With a fixed pulley, there is no increase of power (i.e. no mechanical advantage), only a change of direction.

Is this change of direction ever an advantage?

Give an example.

Where have you seen a fixed pulley used?

Experiment 37. — Remove the bricks from the end of the cord. Fasten one end of the cord to the fixed support, pass the cord around the pulley, and fasten the other end of it to the hook of the spring balance. Support the bricks from the pulley, and hold the balance as shown in Fig. 26. A pulley thus used is called a *movable* pulley.

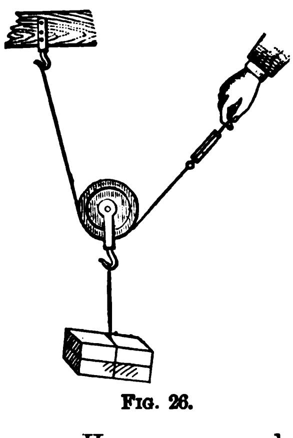

FIG. 26.

Is the apparatus in equilibrium?

What is the weight of the bricks?

How many pounds does the balance indicate that you are lifting?

With a movable pulley in equilibrium, how does the power compare with the weight?

Into how many supporting sections does the movable pulley divide the cord?

What part of the weight does each section of the cord support?

With a single movable pulley having a continuous cord, a given power will support a weight .... as great as itself.

What advantage is gained by the use of such a pulley?

Where have you seen such a pulley used?

Can you devise a movable pulley supported by three sections of the cord?

In such a case, how will power and weight compare when the apparatus is in equilibrium?

With apparatus arranged as in Fig. 27, how do power and weight compare?

What advantage has the arrangement shown in Fig. 27 over that shown in Fig. 26?

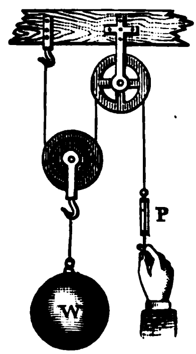

FIG. 27.

THE INCLINED PLANE.

Experiment 38. — Rest one end of a smooth hard board, 4 feet long, upon the table, and support the other end so

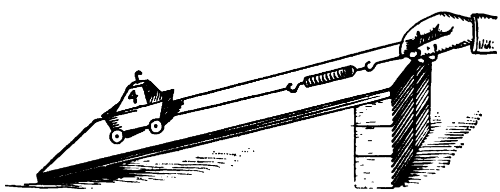

FIG. 28.

that it is 1 foot above the table. The upper surface of this board is an *inclined plane*. Upon this inclined plane,

place a toy car carrying a four-pound weight. See that the bearings are well oiled, and that the wheels turn easily. Pull the car up the plane as shown in Fig. 28, holding the string and balance parallel to the plane.

Compare the reading of the scale of the balance with the weight of the car and its burden.

Repeat the experiment with an eight-pound weight, and make a like comparison.

Repeat the experiment with a ten-pound weight, and make a like comparison.

The weight of the car and its burden is the ***load;*** the pull indicated by the balance is the ***power.*** For each of the three tests just made, multiply the length of the plane (4 feet) by the power, and the height of the plane (1 foot) by the load; compare the products.

Reduce the height of the plane to half a foot and repeat the three tests.

In each case, compare the product of the length and power with the product of the height and load, as before.

The length of an inclined plane multiplied by ---------- equals the height of the plane multiplied by -----------.

QUESTIONS FOR THOUGHT AND READING.

1. Where must the fulcrum of a ten-foot lever be placed in order that 2 pounds at one end shall just balance 8 pounds at the other end?

2. To which class of the simple machines does the wheel-barrow belong?

3. When a boat is rowed, the oar becomes a lever. What is the fulcrum, what the load, and what the power?

4. Give three illustrations of the familiar use of an inclined plane.

5. With a fixed pulley, what power will support a weight of 600 pounds? With a single movable pulley?

6. How may friction modify the laws of equilibrium and of mechanical advantage in the case of machines? Is it ever an advantage?

---

5. THE MECHANICS OF LIQUIDS.

(THE TYPICAL LIQUID IS WATER.)

LEVEL SURFACE.

Experiment 39.—Pour a quart or two of sand into a pan. Pour a quart or two of water into a similar pan.

What force brought the water to a level?
What property of water made this possible?
Why has not the sand a level surface?
When the ocean is calm, has it a level surface?
Has it a plane surface?
What is the difference between a level surface and a plane surface?
Give examples of each.

INTERNAL PRESSURE.

Experiment 40.—Close the stem of a clay pipe with wax. Fill the pipe with water that has been colored with red ink. Tie tightly a piece of rubber tissue, such as you may get of a dentist, over the bowl of the pipe. Hold the pipe with its stem pointing upward and

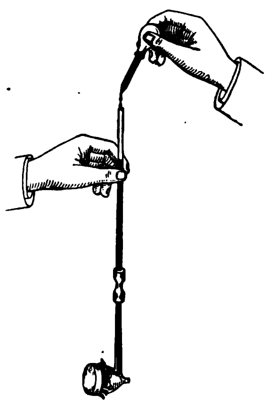

FIG. 29.

remove the wax. By means of a short piece of rubber tubing, connect the stem of the pipe to the piece of glass tubing used in Experiment 7. By means of a medicine-dropper or a pen-filler, half fill the tube with the colored liquid, and mark the level of the liquid in the glass tube by a thread tied at that point. Holding the pipe and glass tube upright, try to find some easy way of forcing the level of the liquid above the point marked by the thread.

Fig. 30.

Gradually lower the pipe into a deep vessel of water, and notice the effect upon the level of the liquid in the glass tube.

How do you explain the rising of the liquid in the tube?

Gradually raise the pipe, and notice the level of the liquid in the tube.

How do you explain the falling of the liquid in the tube?

What does this experiment teach about the pressure within the liquid?

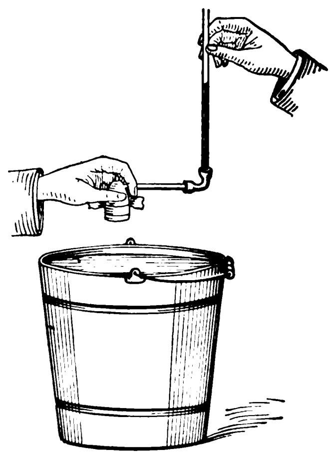

Fig. 31.

Experiment 41. — Hold the pipe in a horizontal position, mouth downward, and gradually lower it into a pail of water. Notice the effect upon the level of the liquid in the vertical tube.

What does this teach about the pressure within the liquid that was not taught by Experiment 40?

Hold the pipe in different positions, and at different depths, and notice the effect in each case.

Liquids exert pressure in .... directions, and the pressure increases with the ....

Experiment 42. — Punch small holes in the bottom and sides of a small tin can, and push the can down a little way into a pail of water.

What happens?

Explain this from the principle of liquid pressure.

Why does water exert lateral pressure while a stone does not? What force causes this pressure? Explain.

FIG. 32.

TRANSMISSION OF PRESSURE.

Experiment 43. — To the stem of the pipe used in Experiment 40, connect the tube of a small funnel, using a piece

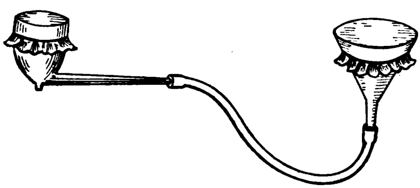

FIG. 33.

of rubber tubing about a foot long. When the apparatus is filled with water, tightly tie rubber tissue over the

mouth of the funnel. Hold the mouth of the pipe and that of the funnel at the same level, and press upon the rubber tissue of the funnel.

What effect upon the rubber tissue of the pipe do you notice?

What part does the water play in this experiment?

What property of the water enables it to do this?

Hold the pipe in various positions, and repeat the experiment.

In what direction will a liquid transmit pressure?

Keeping the two pieces of tissue at the same level, hold the pipe so that its bowl faces in different directions. In each case, press with equal force upon the rubber tissue of the funnel, and see if the rubber tissue of the pipe is stretched to a greater extent in one case than in another.

How do you explain the result?

Liquids transmit pressures _________ in ________ directions.

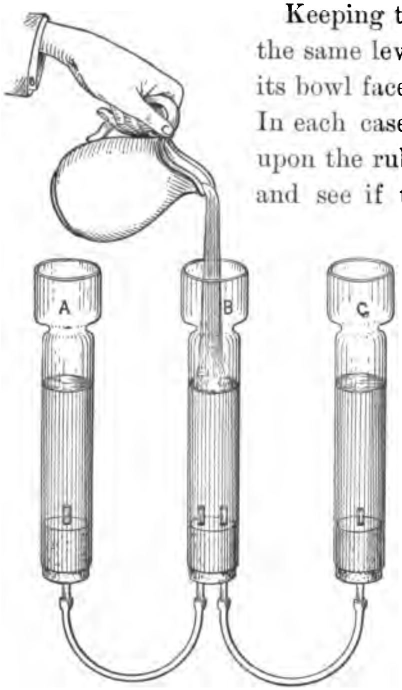

FIG. 34.

WATER IN PIPES.

Experiment 44. — Tightly fit to three argand lamp chimneys fine-grained corks that

have been perforated and provided with short pieces of glass tubing, as shown in Fig. 34. Connect the chimneys by means of rubber tubing. Support the chimneys upright, and pour water into one of them, as *B*. Notice the level of the liquid in *A* and *C*. Hold *A* a little higher than *B* and *C*, and notice whether the three liquid surfaces remain at the same level.

When a liquid stands at rest in several communicating pipes or vessels, it will have the -------- level in each.

This principle is illustrated on a large scale by artesian wells, and the system of water supply of most cities. Fig. 35 represents an artesian well. *AB* and *CD* repre-

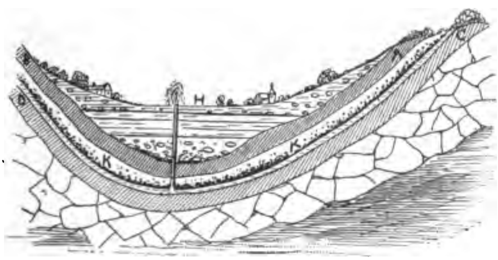

FIG. 35.

sent earth strata through which water cannot pass, and *KK* an intervening layer of gravel or sand, into which water filters on the surface of a hill or mountain, perhaps many miles away. When the well at *H* passes through the layer, *AB*, water rises to the surface and spouts into the air like a fountain. Why?

Draw a similar diagram for a hillside spring.

Experiment 45. — Remove the rubber tubing from one of the chimneys of Experiment 44, and insert a glass tube

about 6 inches long that has been drawn out to a jet at one end. Pour water into *C*, and hold the jet lower than the level of the water in the chimneys.

What happens?
Explain the operation of a fountain.
How high must the water reservoir or tower of a city be?

FIG. 36.

How does the water get into the reservoir?

How are the water mains and other supply pipes kept from freezing?

In case of a fire in a city, how high can water be thrown from a hydrant (fire-plug) without the aid of an engine?

What is the force that causes the water to flow from a faucet?

Can you diagram the water-works system of your city or town?

Try to do so.

ARCHIMEDES PRINCIPLE.

Experiment 46. — Remove the primer from a No. 12 metal cartridge-shell and insert a screw-eye into the opening. Fill the shell with melted lead. When it is cool, slip it into a No. 10 cartridge-shell; it will just fit.

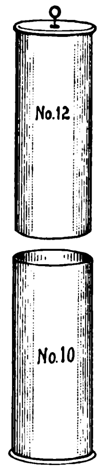

FIG. 37.

How does the volume of the filled shell compare with the capacity of the empty shell?

If immersed in water, what volume of water will the filled shell displace?

Prove it.

Experiment 47. — Insert a small screw-hook at the center of the under side of each scale-pan of the balance used in Experiment 34. By a thread, suspend the filled cartridge-shell from one of the hooks, place the empty shell on the pan above it, and counterbalance them with weights in the other scale-pan. Hold a tumbler of water so that the filled shell is immersed in the liquid.

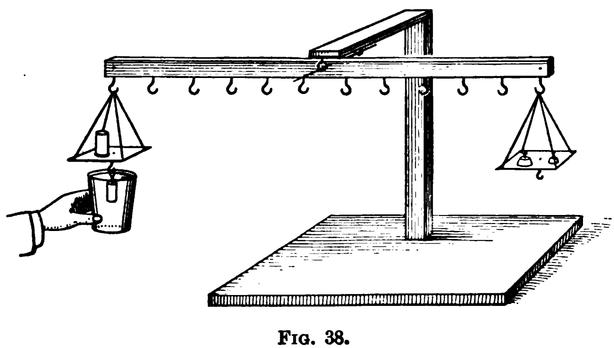

FIG. 38.

What effect upon the weight of the shell does its immersion in water seem to have?

Keeping the lower shell still immersed, carefully fill the upper shell with water.

What effect do you notice?

How does the quantity of water poured into the upper shell compare with the quantity of water displaced by the lower shell?

How much weight must the lower shell have lost by its immersion?

A body immersed in water loses the weight of an equal -------- of -----------.

This is known as the *Archimedes principle.*

We say that water has *buoyancy.*

To what is buoyancy due? Explain.

Why does it require less effort to lift a heavy stone when it is in water than it does when it is in air?

DENSITY OF SOLIDS.

Experiment 48.— Suspend the filled cartridge-shell beneath the scale-pan and counterbalance it with small wire tacks in the other scale-pan. Count these tacks. They

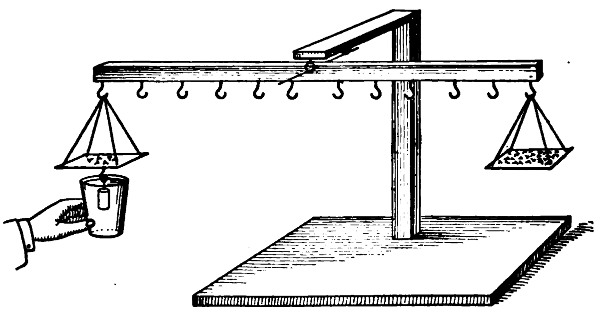

FIG. 39.

represent the weight of the filled shell. Immerse the shell in water as before, and place enough tacks in the pan above to restore the equilibrium. Count these tacks.

> The tacks just counted represent the weight of what quantity of water?

Divide the greater number of tacks by the lesser number of tacks. The quotient is the density (specific gravity) of the filled cartridge-shell. It is an abstract number and indicates that the cartridge-shell is that many times as heavy as water.

The density of a body (i.e. its specific gravity) is the quotient obtained by dividing the weight of the body by the weight of a like volume of ___________.

This divisor is found sometimes in one way and sometimes in another.

Experiment 49.— Determine the density of the glass stopper of a bottle. Use tacks for weights as before.

DENSITY OF LIQUIDS.

Experiment 50.— Immerse the filled cartridge-shell in kerosene, and determine its loss of weight in that liquid. Use tacks as weights.

> This loss is equal to the weight of what volume of kerosene?
>
> In Experiment 48, you ascertained the loss of weight of the same body in water. How much was that loss?
>
> It is equal to the weight of what volume of water?

Divide the loss of weight in kerosene by the loss of weight in water; the quotient will be the density of the kerosene.

If the density of a body is less than unity, is that body heavier or lighter than water?

Is kerosene heavier or lighter than water?

Prove your answer by an experiment.

Experiment 51.— Weigh an empty bottle, using tacks as weights. Fill the bottle with water and weigh it. Fill the bottle with kerosene and weigh it. By subtraction, you can ascertain the weights of equal volumes of kerosene and of water. From these weights, determine the density of kerosene. Compare this result with that obtained in Experiment 50.

Experiment 52. — Make a strong solution of salt in water (brine). Determine its density.

Which is heavier, salt water, or fresh water?

What reason can you give for this?

FLOATING BODIES.

Experiment 53. — Push a block of wood under water. Let go of it. Observe what happens.

FIG. 40.

What force causes this movement?

What would happen if the block was heavier than an equal volume of water?

What if it was just as heavy? Half as heavy? A third as heavy?

Experiment 54. — Fill a cup with water and stand it in a saucer. Float as large a block of hard wood as possible in the cup, and catch the overflow of water in the saucer. Wipe the block dry and weigh it. Weigh the water in the saucer. Use tacks as weights. Compare the weight of the block with the weight of the water it displaced.

FIG. 41.

A floating body displaces its own ____________ of water.
An immersed body displaces its own ___________ of water.

How much water will an ironclad ship displace?

Why will a solid piece of iron sink in water?

What can be done to it to make it float?

Will a floating ship displace a greater or less weight of salt water than it will of fresh water?

Will a floating ship displace a greater or less volume of salt water than it will of fresh water?

Try to think out a way of determining the density of a solid that will not sink in water.

QUESTIONS FOR THOUGHT AND READING.

1. A cylindrical cork floats vertically with 1 inch above water and $\frac{2}{3}$ of an inch below the liquid surface. What is its density?

2. How many cubic feet of cork floating in water will just support above water a man weighing 150 pounds?

3. Why does a vessel sink deeper in fresh water than in salt water?

4. Explain by diagram the principle of the hydraulic press.

5. Who was Archimedes?

6. What is the pressure upon the bottom of a pan full of water if the area of the bottom is $\frac{3}{4}$ of a square foot, and the pan is 4 inches deep?

7. Why is it difficult to keep the feet upon the bottom of the lake when the water is just up to the chin?

8. Why is the current of a river faster in the middle of the stream than it is near the banks?

9. Why is the wall of a dam made thicker at the base than at the top?

10. Why does a bucket full of water suddenly become so heavy when lifted from the water of a well or spring?

11. Water may be slightly heaped up in a vessel. Explain.

12. What is a hydrometer?

---

6. THE MECHANICS OF GASES.

(THE TYPICAL GAS IS AIR)

NORMAL CONDITION OF THE ATMOSPHERE.

Experiment 55. — Tightly tie a piece of rubber tissue over the mouth of a small bottle. Place this in a larger bottle, and close the latter with a snugly fitting cork through which a bent tube passes. Suck part of the air from the large bottle, and notice the effect upon the rubber tissue. Admit air to the larger vessel, and notice the effect upon the rubber tissue.

FIG. 42.

What is it that pushed the rubber tissue outward?

Why did it not do this before air was removed from the larger bottle?

In its normal condition, our atmosphere is compressed and elastic,

ATMOSPHERIC PRESSURE.

Experiment 56. — Suck air from the funnel used in Experiment 43, and readmit it. Repeat the experiment, holding the mouth of the funnel in different positions. Explain the movements of the rubber tissue.

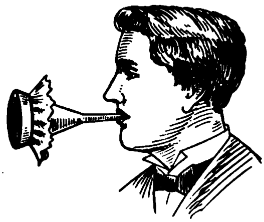

FIG. 43.

In what direction does the atmosphere press?

What force causes liquid pressure?

What force causes atmospheric pressure?

Why does not atmospheric pressure force our windows inward?

The atmosphere exerts pressure in .... directions.

At the sea-level, the pressure of the atmosphere is nearly 15 pounds to the square inch.

Why does it not crush us to death?

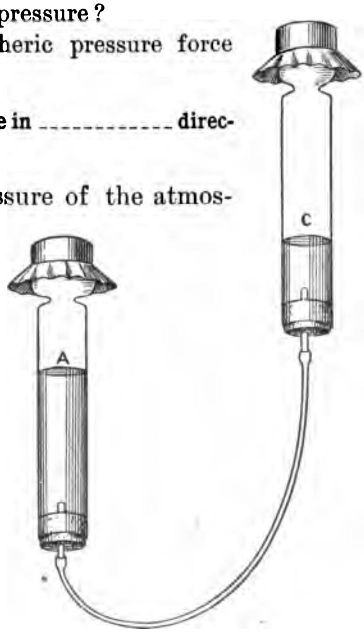

FIG. 44.

Experiment 57. — Tie rubber tissue over the mouths of two of the lamp chimneys used in Experiment 44. Half fill the chimneys with water, and connect them by a piece of rubber tubing about 2 feet long. Hold the two chimneys erect. Raise and lower one of

them, and notice the effect upon the rubber tissue of each.

Explain the movements of the rubber tissues.

Support the chimneys at the same level, and press downward upon the rubber diaphragm of one.

> What effect upon the water in the other chimney or upon the other diaphragm do you notice?
>
> How does this experiment illustrate atmospheric pressure?
>
> In what way does it illustrate the transmission of pressure by air?
>
> How do the causes of the movements of the rubber diaphragms compare with the causes of the movements of our lungs in breathing?
>
> What is the use of the diaphragm of the animal body in breathing?
>
> Is it proper to say that we "draw" our breath?

Experiment 58. — Dip one end of a glass tube into water.

FIG. 45.

> How does the atmospheric pressure upon the surface of the water within the tube compare with the atmospheric pressure upon the same area of the surface of the water outside the tube?
>
> If part of the air in the tube is removed, how will the pressures then compare?

Suck some of the air from the tube.

> What happens?
>
> Can you give a reason for this?
>
> What force causes the water to move up the tube?

Experiment 59. — Fill a tumbler with water, place a slip of thick paper over its mouth, and hold it there while you invert the tumbler. Then remove the hand from the paper.

FIG. 46.

> What supports the paper?
> What supports the water?
> What two downward pressures are acting upon the upper surface of the paper?

Experiment 60. — Push the glass tube used in Experiment 45 through a perforation in a cork that snugly fits a quart bottle. Slip a short piece of snugly fitting rubber tubing over the outer end of the glass tubing, and insert the cork so that the jet shall project into the bottle. Suck as much air as possible from the bottle, pinch the rubber tubing tightly, place its free end under water, and remove the pressure.

FIG. 47.

Explain the movement of the water.

If all the air was removed from the bottle, the empty space would be called a *vacuum*.

> If there was a vacuum in the bottle, how much water would be forced into the bottle?
> Air presses *downward*. How, then, can the air push water *upward* into a vacuum?

Experiment 61. — Remove the jet-tube from the cork of the bottle used in Experiment 60, and push it through the cork of the same or of another bottle so that it reaches nearly to the bottom of the bottle, leaving the jet end

extending an inch or so on the outside. See that there is enough water in the bottle to cover the inner end of the tube. Apply the lips to the end of the tube, and force as much air as possible into the bottle. Remove the bottle as quickly as you can.

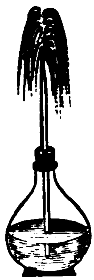

Fig. 48.

Explain any effect that you notice.

The elastic force of a gas is proportional to its density.

Is the atmosphere more dense near the surface of the earth or far above it? Why?

THE BAROMETER.

Experiment 62. — Place about an inch of colored water in the larger bottle used in Experiment 55. In addition to the bent tube then used, pass a straight glass tube, about 2 feet long, through the cork, and see that its lower end dips into the water.

How does the density of the air in the bottle compare with the density of the air outside?

If there was any difference of density, what movement of air would take place?

Notice the level of the liquid in the long tube.

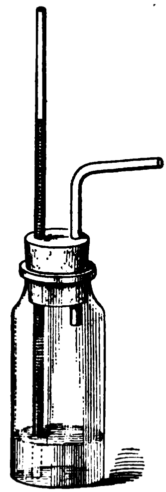

Fig. 49.

Apply the lips to the end of the bent tube and force air into the bottle.

Notice the level of the liquid in the long tube.

Allow a little of the air to escape from the bottle.

Notice the level of the liquid in the long tube.

What will cause a rise of the liquid column?

What will cause a fall of the liquid column?

What will a variation in the height of the liquid column indicate?

Experiment 63. — Select a stout glass tube about 35 inches long, about a quarter of an inch in internal diameter, and closed at one end. Twist a piece of paper into the shape of a hollow cone, and, using it as a funnel, fill the tube with mercury. With an iron wire, remove any air-bubbles that you see in the tube. Hold a finger firmly over the open end of the tube; invert the tube, and place the open end in a cup of mercury. When you remove your finger, observe the upper end of the mercury column.

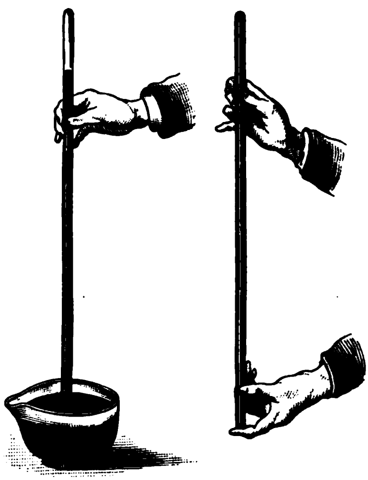

FIG. 50.

What did you notice?

What is in the tube above the mercury?

What is the vertical distance, in inches, from the level of the mercury in the cup to the top of the mercury column?

What force supports this mercury column?

Why does not the mercury fill the tube?

Do you think that it would fill a tube only 25 inches long?

Suppose you try it.

How would an increase in the density of the atmosphere affect the height of the mercury column in the 35-inch tube?

How would a decrease of density affect it?

This experiment illustrates the principle of the *barometer*. The tube and cup may be supported by a wooden frame, and a scale of inches divided to sixteenths placed beside the upper part of the tube, as shown in the figure.

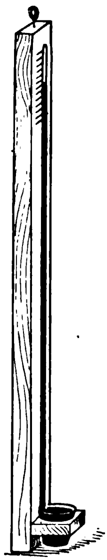

FIG. 51.

Stand the apparatus in a protected place, and make daily observations for a week or two, to see if the height of the mercury column varies.

If we should carry a barometer to the top of a mountain, would there be any variation in the height of the mercury column? Why?

What use of the barometer is suggested by this fact?

Keep a daily record of the weather and of the barometer readings, and see if you can detect any relation between the two.

Can you think of any way in which the barometer may be used for forecasting weather changes?

Use a weather map in this connection.

THE LIFT-PUMP.

Experiment 64. — Procure a wooden spool that will move freely inside an argand lamp chimney. Wind yarn upon the spool until it fits the chimney snugly. Tack

the edge of a little piece of thin leather or sheet rubber to the upper end of the spool so that it will cover the end of the hole through the spool, thus making a *valve* opening upward. Fasten the free ends of the branches of an umbrella-rib to the sides of the spool. The branches should pass through notches cut in the upper end of the spool. Allow the free end of the umbrella-rib to extend upward beyond the large end of the chimney to serve as a handle. Into the perforation of a cork that snugly fits the lower end of the chimney, push the end of a glass tube about 6 inches long. This tube should pass only part way through the cork. To the end of the cork and over the end of the tube, tack another valve. Put the cork in position as shown in the figure. Both valves open toward the big end of the chimney. You now have a lift-pump. The spool is the *piston;* the umbrella-rib is the *piston-rod;* the chimney is the *barrel;* and the glass tube is the *suction-pipe* of the pump.

FIG. 52.

Put the parts together, and soak the apparatus in water. Pour the water out of the barrel, and place the free end of the suction-pipe in water.

How does the density of the air in the barrel below the piston compare with that of the air outside the pump?

How does its pressure upon the water inside the suction-pipe compare with the pressure upon the water outside?

Raise the piston.

How does this affect the density of the air in the barrel below the piston?

How does it affect the downward pressure upon the water in the suction-pipe?

What effect of raising the piston do you notice?

Explain it.

Quickly lower and raise the piston.

What effects of these movements of the piston do you observe?

Explain them.

If the pump does not act promptly, "prime it" by pouring a little water into the upper end of the chimney.

When the pump is in action and the barrel is filled with water, notice the movement of each valve at each stroke of the piston.

Explain the movements of the valves.

As the piston rises, what force pushes the water above the inlet-valve at *X*?

Why did it not push the water up before the piston was raised?

If the mercury column of the barometer is 30 inches high, and the density of mercury is 13.6, what will be the maximum height of a similar column of water?

What is the greatest height that the piston of a lift-pump may be above the level of the water that is to be raised?

Can water be pumped to a height greater than this?

THE FORCE-PUMP.

Experiment 65. — Make another perforation in the lower cork of the lift-pump used in Experiment 64, and insert a short piece of glass tubing. Plug water-tight the lower end of the hole through the spool-piston. To the small end of a second lamp chimney, fit a cork that has a short

glass tube and valve, and connect the two chimneys with a piece of rubber tubing as shown in the figure. Close the upper end of the second chimney with a cork that carries a J-shaped glass tube, the long arm of which extends nearly to the valve beneath. Support the two chimneys side by side, and work the solid piston up and down. Observe the movements of the valves and of the water.

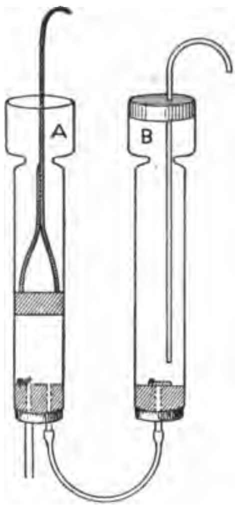

FIG. 53.

Why is this called a force-pump?

Explain the action of a force-pump.

Is the water thrown from the J-tube in an intermittent or in a steady stream?

The space in the chimney, *B*, above the water, is called an *air-chamber*.

Does the air of the air-chamber contribute to the steadiness of the stream thrown by the pump?

What two properties of the air contribute to this result?

Where have you seen a force-pump used?

Are pumps ever made for pumping air?

Where have you seen one used?

Do they act like water-pumps?

How high may water be raised with a force-pump?

What kind of a pump is a fire-engine?

What kind of a pump is used with a bicycle?

THE SIPHON.

Experiment 66. — Bend a piece of glass tubing about 8 inches long into a U-shape. Place two tumblers side

by side and fill one of them with water. Fill the U-tube with water, close one end with a finger, and place it in the tumblers, as shown in the figure.

FIG. 54.

What happens when you remove your finger?

The bent tube thus used is called a *siphon*.

How long does the water continue to flow through the tube?

Lower one of the tumblers a little.

What happens?

The vertical distance from the level of the upper liquid to the highest point of the bent tube is the length of the

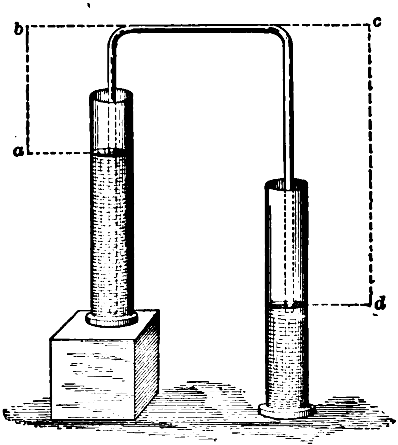

FIG. 55.

short arm of the siphon; the vertical distance from the highest point of the tube to the lower end of the tube, or

to the level of the liquid into which it dips, is the length of the *long arm* of the siphon. In Fig. 55, these two lengths are represented by *ab*, and *cd*.

What upward force is exerted upon the water in each arm?

Are these upward forces equal or unequal?

What force acts against the atmospheric pressure, and tends to pull the water down in each arm?

In which arm is this downward pull the greater? Why?

In which arm will the motion be downward?

If the open ends of the siphon have an area of 1 square inch each, what will be the upward pressure at each? Give your answer in pounds.

Suppose that the water in the short arm weighs 2 pounds, and the water in the long arm, 4 pounds.

What is the downward pressure in the short arm? Give your answer in pounds.

Considering only the short arm, what two forces operate upon the water in it?

What is the resultant of these two forces? Give your answer in pounds.

In what direction will this resultant tend to move the water in the short arm?

Considering only the long arm, what two forces operate on the water in it?

What is the resultant of these two forces? Give your answer in pounds.

In what direction will this resultant tend to move the water in the long arm?

Now consider these two resultants and the siphon as a whole.

In what direction does the first resultant tend to move the water in the siphon?

With how much force does it tend to move it in that direction?

In what direction does the second resultant tend to move the water in the siphon?

With how much force does it tend thus to move it?

Do these two resultant forces act in the same direction or in opposite directions?

Will the resultant of the two resultants be found by addition or by subtraction?

What is the resultant of the two resultants? Give your answer in pounds.

In what direction does this final resultant act?

With what force is the water pushed through the siphon? Give your answer in pounds.

Suppose that the long arm is lengthened until the water in it weighs 7 pounds.

With a force of how many pounds will the water then be pushed through the siphon?

Suppose that the two arms are equal.

With a force of how many pounds will the water then be pushed through the siphon?

Does the water run toward the open end of the longer or of the shorter arm?

How can you increase the rate at which water will flow through a siphon tube of given diameter?

Illustrate this by using a pail of water on the table, a yard of small rubber tubing, a quart cup, and a watch.

What pressure lifts the water to the top of the siphon?

The height over which water may be siphoned varies as the height of the barometer column varies. Why?

Over how high a ridge can water be siphoned when the barometer stands at 30 inches? Remember that the density of mercury is 13.6.

QUESTIONS FOR THOUGHT AND READING.

1. What is the force that causes water to flow through a siphon? Which can be siphoned to a greater height, water or kerosene? Why?

2. Look at the barometer and tell to what height mercury can be siphoned now.

3. What kind of a pump is used in filling bicycle tires? Diagram it.

4. Will a balloon float in a vacuum? Why?

5. Why will the fire in the stove burn better on a clear, cold day than on a warm, foggy one?

6. Why does water gurgle as it flows out of a jug or bottle?

7. Why is it necessary to remove the stopper from the top of a kerosene can before the oil will flow freely from the spout?

8. When the street is very muddy, we sometimes "walk out of our overshoes." What force pulls the shoes off? Explain.

9. What property of air makes it useful in bicycle tires?

10. How could you use a mercury column to determine the number of pounds of atmospheric pressure to the square inch?

11. Can a bird fly in vacuum? Explain.

CHAPTER III.

SOUND.

NATURE AND CAUSE OF SOUND.

Experiment 67. — While a tuning-fork is sounding, hold a suspended ball of pith or cork lightly against one of the prongs of the fork.

Explain the motion of the ball.

FIG. 56.

Make a similar experiment with a sounding bell.

Experiment 68. — Sound a tuning-fork and just touch a water surface with one of its prongs.

Explain the production of the spray.

What must be the condition of the prongs of the fork when it is sounding?

Sound is caused by the rapid vibrations of some body of matter.

Think of some other way in which you can show this to be true.

Sound is a wave motion that is capable of producing the sensation of hearing.

TRANSMISSION OF SOUND.

Experiment 69. — It has been shown by countless experiments that sound will not travel in a vacuum. This may be fairly well illustrated by placing a watch upon cotton batting under the receiver of an air-pump, and pumping the air from the receiver. The ticking of the watch will be heard but faintly if at all.

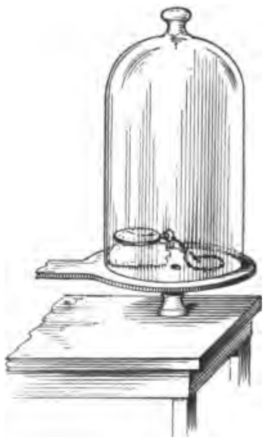

FIG. 57.

Think of some illustration of the fact that sound can travel in a gas.

Think of some illustration of the fact that sound can travel in a liquid.

Think of some illustration of the fact that sound can travel in a solid.

The thing through which sound travels is called a *medium* of sound.

The transmission of sound requires a material medium.

When a sonorous body vibrates, it sets in motion the particles of the medium through which the sound travels. As each particle of the medium vibrates, it sets in motion the particle next to it, and this, in turn, transmits its motion to the next particle; and so on until the vibrations reach the ear.

This idea is beautifully illustrated by Professor Tyndall. He imagines five boys placed in a row, as shown in Fig. 58.

"I suddenly push *A*; *A* pushes *B* and regains his upright position; *B* pushes *C*; *C* pushes *D*; *D* pushes *E*; each boy, after the transmission of the push, becoming himself erect. *E*, having nobody in front, is thrown forward. Had he been standing on the edge of a precipice, he would have fallen over; had he stood in contact with a window, he would have broken the glass; had he been close to a drum-head, he would have shaken the drum. We could thus transmit a push through a row of a hundred boys, each particular boy, however, only swaying to and fro.

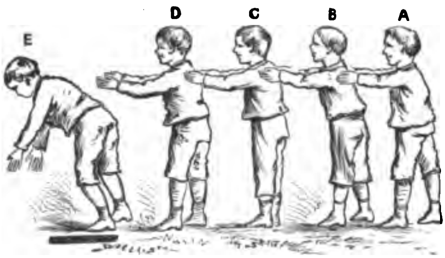

FIG. 58.

Thus also we send sound through the air, and shake the drum of a distant ear, while each particular particle of the air concerned in the transmission of the pulse makes only a small oscillation."

The distance through which the individual particle swings is called the *amplitude of vibration*.

In water waves, each water particle moves up and down, while the wave moves horizontally. The distance from one crest to the next crest, or from one hollow to the next hollow, is a *wave length*. In a sound wave, the particles (generally of air) move to and fro in the line in which the wave is advancing. As the particles move forward, they are crowded unusually, *i.e.* the medium is compressed at that point; as they swing backward, they are separated more widely, *i.e.* the medium is rarefied at

that point. A sound wave consists, therefore, not of a crest and hollow but of a *condensation* and a *rarefaction.*

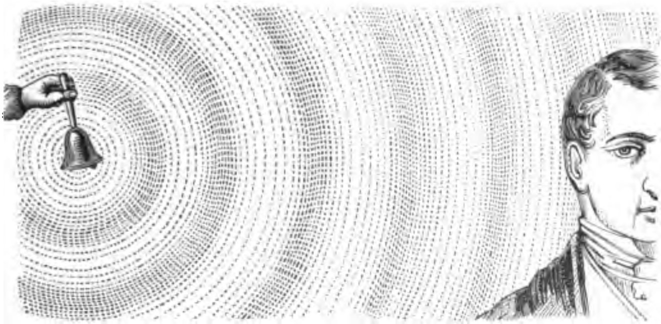

FIG. 59.

The distance from one condensation to the next condensation, or from one rarefaction to the next rarefaction, is a *wave length.*

Experiment 70. — Provide a wooden rod about half an inch square, and five or six feet long. Place one end of

FIG. 60.

this rod (preferably made of light, dry pine) against the panel of a door; hold the rod horizontal, and place the handle of a vibrating tuning-fork against the other end. Notice the sound given out by the panel. The common "string telephone" (Fig. 60) is a more familiar illustration of the transmission of sound by a solid.

The velocity of sound is different in different substances.

Experiment 71. — Hold your ear against a railway rail or a long water-pipe. Let some one a long distance away strike the rail or pipe a sharp blow with a hammer. Notice which sound reaches your ear first, that which comes through the iron, or that which comes through the air.

What does this teach?

The velocity of sound in the air at the temperature of freezing water is 1,090 feet per second.

At the more common temperature of 60° Fahrenheit, the velocity of sound is about 1,120 feet per second.

Which travels faster, sound or light?

How can you prove this? Remember that you see an object by the light that comes from it to your eye.

How do you account for the formation of an echo?

An echo shows that sound may be ....

If the echo of your voice is heard 3 seconds after your shout, how far away is the reflecting surface?

LOUDNESS.

Experiment 72. — Gently pluck the tightly stretched string of a violin or a guitar. Notice the amplitude of

vibration and the loudness of the tone. Increase the amplitude of vibration, and notice the effect upon the loudness.

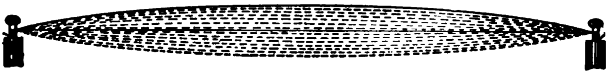

FIG. 61.

Loudness depends upon ____________.

The greater the ___________, the louder the tone.

PITCH.

Experiment 73. — Draw the back of a knife-blade slowly across the teeth of a comb. Draw it more rapidly, and notice the difference in pitch.

How do you account for this difference?

Pitch depends upon ___________ of vibration.

The more ___________ the vibrations, the higher the pitch.

TONES PRODUCED BY STRINGS.

Experiment 74. — Stretch violin or other musical strings across the top of a box, as shown in the figure, and deter-

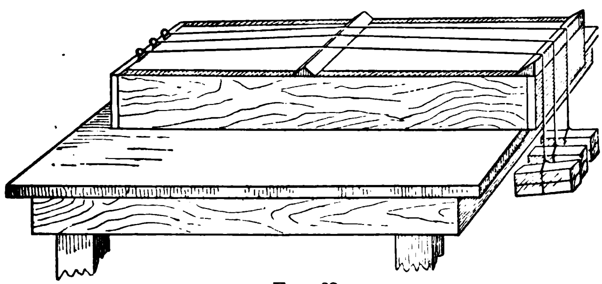

FIG. 62.

mine how pitch varies with the tension, the length, and the size or weight of the strings. Fine wires of different sizes and materials may be used. Consider the length of each string to be the distance between the triangular blocks of wood that support it. The block at the middle of the box is movable.

The shorter the string, the ___________ the pitch.
The tighter the string, the __________ the pitch.
The larger the string, the ___________ the pitch.
How are tones of different pitch obtained on a violin?
How are tones of different pitch obtained on a piano?

QUESTIONS FOR THOUGHT AND READING.

1. It is said that the moon has no atmosphere. What effect would this have upon sound there?

2. When thunder is heard in 5 seconds after a flash of lightning is seen, how far away is the lightning?

3. Two strings are of the same length, size, and material, but when they are sounded, one produces a tone of a higher pitch than the other. Explain how this can be.

4. How far away is a cliff when the echo of your voice comes back from it in 4 seconds?

5. Why do you see the smoke from a gun before you hear its report?

6. Moisten the tip of the finger and pass it around the edge of a finger-bowl or thin tumbler, using but slight pressure. Account for the tone that is produced.

7. Why is sound transmitted so readily through a speaking tube?

CHAPTER IV.

HEAT.

1. NATURE OF HEAT, TEMPERATURE, ETC.

NATURE OF HEAT.

Experiment 75. — Swing the pendulum used in Experiment 28. Notice that the bullet is one thing, and that the motion of the bullet is another thing.

Is the bullet matter?
Is the motion of the bullet matter?
Is the motion just as real as the matter?

Imagine the bullet to dwindle to a molecule while it is swinging.

Is the molecule matter?
Is the motion of the molecule matter?
Is the motion of the molecule just as real as the molecule itself?

Try to imagine the molecules of the air in a closed bottle to be in constant motion among themselves. The molecules are in such motion.

Try to imagine the molecules of the water in a bottle full of water to be in constant motion among themselves. They are in such motion.

Try to imagine the molecules of the glass bottle itself to be in constant motion among themselves. They are

in such motion. When the bottle is hot, these molecular motions are more vigorous than they are when the bottle is cold.

Heat is not matter; it does not take up room; it does not weigh anything.

Heat consists of the motion of the molecules of matter, and is a form of energy.

It causes the sensation of warmth by which we generally recognize it. Any other form of energy may be converted into heat.

TEMPERATURE.

When a kettle of water is placed on a hot stove, what change takes place in the water? Why?

When a bottle of water is placed in an ice-chest, what change takes place in the water? Why?

Can the water in the kettle melt more ice before or after it was put on the stove? Why?

Can the water in the bottle melt more ice before or after it was put into the chest? Why?

The condition of a body considered with reference to its ability to give up heat to other bodies is called the *temperature* of that body. Just as water flows from a high to a low level, so heat flows from a point of high temperature to one of low temperature.

Experiment 76. — Into one basin put hot water; into a second basin put ice-cold water; into a third basin put water at the temperature of the room. Put the right hand into the hot water and the left hand into the cold water, and hold them there for some time. Transfer the right hand from the hot water to the water in the third

basin, and that water will seem cold. Transfer the left hand from the cold water to the water in the third basin; the water that felt cold to the right hand will feel warm to the left hand.

It is evident that our bodily sensations cannot be trusted as a measure of temperature. They are of even less value in the measurement of heat.

A body feels hot when it is imparting heat to us; it feels cold when it is drawing heat from us.

THE THERMOMETER.

The instrument generally used for measuring temperature is called a *thermometer*.

Experiment 77. — Place a thermometer in water that is boiling-hot (Fig. 63), and determine the temperature of the water. Then pack the lower end of the thermometer in chipped ice (Fig. 64), and determine the temperature of melting ice. If you can get some moist snow, pack the thermometer in it, and determine the temperature of the snow.

FIG. 63.

FIG. 64.

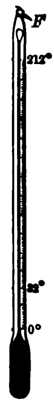

FIG. 65.

Thermometer scales are of different kinds; the one most common in this country is called Fahrenheit's. The temperature of freezing water is called 32 degrees; that of boiling water, 212 degrees (Fig. 65). The interval between these two points is divided into 180 equal parts, each called a degree.

2. PRODUCTION AND TRANSFERENCE OF HEAT.

PRODUCTION OF HEAT.

Experiment 78. — Rub a metal button on the floor or carpet. It soon becomes uncomfortably warm. It was heated by *friction.*

Experiment 79. — Place a nail or coin on an anvil or a stone, and hammer it vigorously. It soon becomes too hot to handle. It was heated by *percussion.* In this way, blacksmiths sometimes heat iron rods to redness.

These experiments illustrate the conversion of the energy of muscular action into the form of energy called heat, which, as we have seen, consists of *molecular motion.*

Experiment 80. — Strike a friction-match. The friction develops heat. This heat aids a *chemical change* (combustion) that develops more heat.

State three ways in which heat may be produced.

There are many other ways of producing heat. The most important of these, *i.e.* the conversion of radiant energy into heat, will be considered in the next chapter.

CONDUCTIVITY OF SOLIDS.

Experiment 81. — Cut off the top of a small oil can; provide a wick; fill the can with alcohol. To prevent loss of alcohol by evaporation when the lamp is not in use, cover the wick with a thimble. This alcohol lamp will be very convenient in many of our

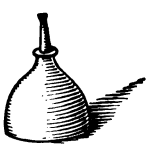

FIG. 66.

experiments in heat. Any small bottle through the cork of which a short metal or glass tube passes may be used instead of the oil can. Hold one end of a piece of stout copper wire about 4 inches long in the flame of the lamp.

Why does the cool end of the wire become hot?

The flow of heat from the hotter to the cooler parts of a body, the heat-motion passing from molecule to molecule, is called conduction.

Experiment 82.— Repeat Experiment 81, using the stem of a clay pipe, or a slate pencil, instead of the wire.

Does the heat-motion move from molecule to molecule as easily now as it did in the wire?

We say that the pipe-stem and the pencil are *poor conductors* of heat, and that the copper wire is a *good conductor* of heat.

Experiment 83. — Wind a strip of paper spirally around a metal cartridge-shell. Fasten the ends of the strip with mucilage. Hold the paper in the flame of the alcohol lamp.

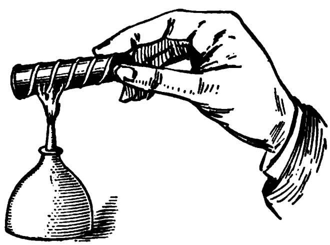

FIG. 67.

Why does not the paper burn?

Of what material are winter clothes generally made? Why?

Are winter clothes worn to keep the cold out or the heat in?

The hollow walls of ice-houses are often packed with sawdust.

Is sawdust a good or a poor conductor of heat?

CONDUCTIVITY OF LIQUIDS.

Experiment 84.— Sink a piece of ice to the bottom of a test-tube nearly full of water, and fasten it there by means of a loosely wound coil of soft wire that snugly fits the inside of the tube. Incline the tube and hold the lamp under the upper part of the water until it boils. Observe the effect of the heat upon the ice.

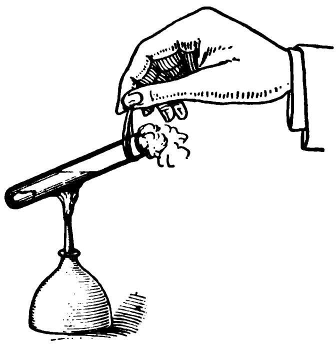
FIG. 68.

Is water a good or a poor conductor of heat?

CONVECTION.

Experiment 85.— Drop some green-wood sawdust into a flask of water, and heat the water from below. Notice the movements of the solid particles.


FIG. 69.

What do these movements indicate?

We shall soon see that heat expands the heated parts of liquids and gases, and thus makes them lighter than the cooler parts.

How is heat transmitted in this case?

This method of transferring heat by the movements of masses of heated fluids is called convection.

Is the Gulf Stream a convection current?

How is the heat carried from a hot-air furnace to the rooms of a house?

Experiment 86.— With a lamp chimney or other large glass tube, a perforated cork, two pieces of glass tubing 4 and 15 inches long respectively, a bit of rubber tubing, a small lamp or a candle, and two coverless crayon boxes, arrange apparatus as shown in Fig. 70. Partly fill the apparatus with water, add a small quantity of green-wood sawdust, carefully heat the tube, and explain how a house is heated with hot-water pipes.

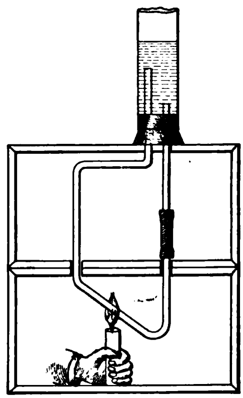

FIG. 70.

DRAFTS.

Experiment 87. — Make a three-quarter-inch hole near one end of the cover of a cigar box or of a pasteboard box. Near the other end, make an inch circle of gimlet holes, and stand a small candle inside the circle. Place lamp chimneys over the holes as shown in Fig. 71. Light the candle. The box should be as nearly air-tight as possible. Soak some blotting paper in a solution of saltpeter and dry it. Ignite this "touch-paper," hold it over the three-quarter-inch hole, and notice the movement of the smoke.

What does the movement of the smoke indicate?

Is hot air heavier or lighter than cold air?

Explain the movements of the air through this apparatus.

What force causes them?

We say that each chimney has a *draft*, upward in one case, and downward in the other.

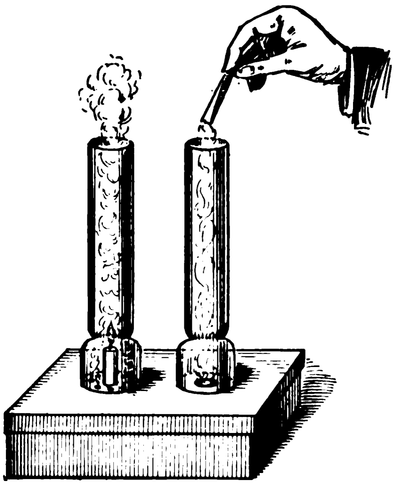

FIG. 71.

Does this experiment help you to understand the origin of a wind? In what way?

Can convection currents exist in gases? Why?

Are the trade-winds convection currents? Why?

Can convection currents exist in solids? Why?

3. EFFECTS OF HEAT.

EXPANSION OF SOLIDS.

Experiment 88. — Select two bottles of equal height. Over the mouth of one, place a small glass plate; into

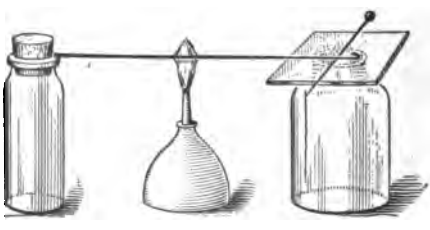

FIG. 72.

the mouth of the other, fit a cork. By means of a bit of

wax, fasten a very slender broomstraw at right angles to a hat-pin, and near its point. Lay the pin upon the glass as shown in the figure. Place one end of a knitting-needle upon the nose of the second bottle, and touching the cork; place the other end upon the hat-pin. Heat the needle with the alcohol lamp. Notice the movement of the straw pointer.

How do you account for the movement of the pointer?

Remove the lamp and allow the needle to cool.

Do you notice any effect? If so, explain it.

Experiment 89. — Twist a copper wire around the larger cartridge-shell used in Experiment 46, thus making a metal ring. The ring should fit the shell snugly enough to support it. Remove the shell, and heat the ring red-hot. See if the ring will support the shell as it did before.

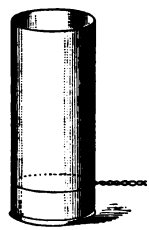

FIG. 73.

What has the heat done to the ring?

Allow the ring to cool, and see if it will again support the shell.

Explain this.

Adding heat to a solid causes it to ....

Withdrawing heat from a solid causes it to ....

Can you think of any practical applications of these facts?

EXPANSION OF LIQUIDS.

Experiment 90. — Fill a bottle with colored water. Provide it with a cork through which passes the glass tube

used in Experiment 7. Push the cork into the bottle so that the water stands in the tube 2 or 3 inches above the cork. Place the bottle in warm water, and notice the level of the liquid in the tube.


FIG. 74.

Explain any movement of the liquid that you notice.

Place the bottle in cold water.

Explain any movement of the liquid that you notice.

Adding heat to a liquid causes it to ....

Withdrawing heat from a liquid causes it to ....

What practical applications of these facts can you think of?

EXPANSION OF GASES.

Experiment 91. — Empty the water from the apparatus used in Experiment 90. Dip the lower end of the tube a little way into a colored liquid, close the upper end of the tube with a finger, and press the cork into the neck of the bottle so that a short liquid column will be forced up the tube as shown in the figure. Breathe upon the bottle, hold in your hands, or warm it in some other way. Notice the effect on the liquid index in the tube.

Explain any movement that you notice.


FIG. 75.

Cool the bottle in any convenient way.

Explain any movement that you notice.

Adding heat to a gas causes it to ....

Withdrawing heat from a gas causes it to ....

What practical applications of these facts can you think of?

LIQUEFACTION.

Experiment 92. — Apply heat to the cup of ice used in Experiment 77, so as to melt the ice very slowly, and constantly stir the mixture with the thermometer. Notice the temperature of the water as long as any of the ice is unmelted.

Call this temperature the *melting-point* of ice.

Does the added heat warm the ice or the water?
What effect does it produce?
Will a cake of ice left in the sun get warm?
What will happen to it?
Can you think of other substances that act in this way?

This change from the solid to the liquid form is called *liquefaction.*

Heat is required to overcome cohesion, and disappears in the process.

SOLIDIFICATION.

Experiment 93. — Pack a small bottle of water in a jar of chipped ice mixed with salt, and leave it in a cool place for half an hour. Then examine the bottle of water.

FIG. 76.

What has happened to the water?
Which gave up heat, the water, or the ice and salt?

What was the effect of the transfer upon the giving body?

What was the effect upon the receiving body?

This change from the liquid to the solid form is called *solidification.*

Freezing is one kind of solidification.

Adding .... to a solid changes it to a ....

Withdrawing .... from a liquid changes it to a ....

When water freezes it gives up heat.

When ice melts it takes in heat, and the heat disappears.

What effect must the freezing of water and the melting of ice have upon the temperature of the atmosphere and other neighboring bodies?

How does the ice in the ice-chest keep the food cool?

Give some other illustration of these principles.

VAPORIZATION.

Experiment 94. — Apply heat to the cup of hot water used in Experiment 77, but do not boil it.

Can you see anything passing from the water into the air?

What is it?

From what part of the water does it seem to come?

Heat the water until it boils.

What do you now see coming from the water?

Does it seem to be formed at the surface of the water, or below it?

This change from the liquid to the gaseous form is called *vaporization.*

What produces vaporization?

The quiet formation of vapor at the surface of a liquid is called evaporation.

The rapid formation of vapor below the surface of a liquid is called boiling.

EVAPORATION.

Experiment 95. — Put like quantities of water into a narrow-necked bottle, a tumbler, and a shallow pan.

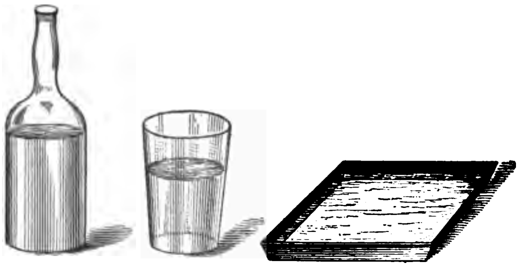

FIG. 77.

Which evaporates the most quickly? Which next?

The ---------- the extent of surface, the ---------- the rapidity of evaporation.

What reason can you give for this?

Experiment 96. — Slightly moisten the surface of a slate. Notice the rapidity with which it dries. Moisten the surface of the slate again. Fan the slate and notice the rapidity with which it dries.

Why this difference?

The motion of the air ---------- the rapidity of evaporation.

What reason can you give for this?

Experiment 97. — Moisten the slate again, and hold it over a lamp or stove. Notice the rapidity with which it dries.

An increase in the temperature of the air ---------- the rapidity of evaporation.

Can you explain this?

Suppose that the air has a large quantity of moisture in it.

How will that affect the rapidity of evaporation? Why?

Evaporation will be ------------ rapid when the air is dry than when it is moist.

Summarize the conditions that affect the rapidity of evaporation.

What kind of weather is most favorable for rapid evaporation?

BOILING-POINT.

Experiment 98. — Apply heat to the cup of hot water used in Experiment 94, and stir the water constantly with the thermometer. Observe the temperature until a considerable part of the water has boiled away.

Was there a continuous rise of temperature?
How long did the temperature rise?
What was the highest temperature observed?

Call this temperature the *boiling-point* of water.

What was the effect of the heat that was added after the water began to boil?

When a liquid is vaporized, heat is required to overcome cohesion, and disappears in the process.

Experiment 99. — Stir a few spoonfuls of common salt into the cup of water used in Experiment 98, apply heat, and determine the boiling-point of the brine.

Is the boiling-point higher or lower than for fresh water?

Try the effect that sugar and cooking-soda in solution have upon the boiling-point of water.

The solution of a solid in a liquid ----------- the boiling-point of the liquid.

Experiment 100. — Boil some water in a thin flask or a test-tube. Remove the lamp, and quickly cork the mouth of the vessel. By this time, the boiling will have stopped. Pour cold water upon the vessel.

FIG. 78.

What effect did the cold water have upon the hot water?

What was in the upper part of the vessel when it was drenched?

What effect had the cold water upon it?

How did that affect the pressure that it exerted upon the hot water?

Can you now see any reason why the hot water boiled again when the cold water was poured upon the vessel?

The boiling-point of a liquid is lowered when the ----------- upon the liquid is lessened.

The boiling-point of a liquid is raised when --------------.

CONDENSATION.

Experiment 101. — Boil a little water in a test-tube, and allow the escaping steam to come into contact with a cool piece of slate or glass. Notice the formation on the slate or glass.

Which is cooler, the slate or the vapor?

Which gave up the more heat to the other?

What change of condition took place?

This change of a vapor to a liquid is called *condensation.*

When a liquid vaporizes, it takes in heat; when a vapor condenses, it gives up heat.

FIG. 79.

What effect must these changes have upon the air and other neighboring bodies?

Why does sprinkling a floor in very warm weather make the room more comfortable?

Can you give other illustrations of the same fact?

Adding heat to a liquid changes it to a ----------.

Withdrawing heat from a vapor changes it to a -------------.

When we breathe into cold air, what happens?

If a mass of warm, moist air comes into contact with a mass of cold air, what will be formed? Why?

Can you now explain how fog, cloud, snow, and rain are formed?

DEW-POINT.

Experiment 102. — In a bright tin dipper, place some finely broken ice, salt, and water, and stir them with a thermometer.

What appears upon the outer surface of the dipper?
Where did it come from?

This is *dew*.

At what temperature did it first appear?

This is the *dew-point* of air.

Why does dew form on the grass at night?
Does it "fall"? Try to devise an experiment to answer this question.

Summarize the effects of adding heat to a body.

Summarize the effects of withdrawing heat from a body.

TEMPERATURE OF MAXIMUM DENSITY.

FIG. 80.

Experiment 103. — Pass a thermometer, and the glass tube used in Experiment 7, through the cork of the bottle used in Experiment 1. The mercury column should show an inch or so above the cork. Fill the bottle with water, and insert the cork firmly so that water rises in the tube several inches above the top of the cork. Mark the level of the water in the tube by tying a thread at that point. If the water retains that level, you may feel sure that the

apparatus is water-tight, as it should be. Now pack the bottle to its mouth in a freezing mixture of salt and snow or chipped ice. Watch for some movement of the water level in the tube.

What movement takes place, upward or downward?
How do you account for that movement?

Shake the bottle occasionally. Watch the water column. If it begins to rise, notice the temperature.

At what temperature did the upward movement begin?
How do you account for that movement?
Had the temperature of the water fallen to the freezing-point?
At what temperature was the water most dense?

Call this the *temperature of maximum density for water.*

Does water begin to expand before or after ice forms?
Does water expand or contract when it freezes?
What common experience proves this?
What makes ice float on water?
If water contracted as it froze, which would be heavier, ice or water?
What would then happen to the ice?
What effect would this have upon climate?

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4. LATENT AND SPECIFIC HEAT.

LATENT HEAT OF WATER.

Experiment 104. — Select two deep, tin cans of the same shape and size. Put about 4 ounces of cool water into one can, and the same weight of chipped ice into the other. Find the temperature of each. Set both cans

at the same instant into a pan of hot water. Keep the contents of both well stirred. When nearly all of the ice is melted, remove both cans at the same instant, and quickly take the temperature of each.

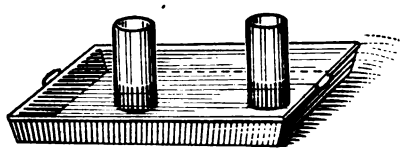

FIG. 81.

How does the second temperature of the water compare with its first temperature?

How does the second temperature of the iced water compare with the first temperature?

The same amount of heat was added to each.

What was the effect of the heat added to the cool water?

What was the effect of the heat added to the ice?

The heat that was used in melting ice and that disappeared in the process is called the *latent heat of water*.

LATENT HEAT OF STEAM.

Experiment 105. — Boil some water. Take its temperature when it begins to boil, and again two minutes later.

How do the two temperatures compare?

During the two minutes, heat was constantly added to the water.

The heat did not raise the temperature; what did it do?

The heat that was used in vaporizing the water and that disappeared in the process is called the *latent heat of steam*.

The latent heat of a substance is the amount of heat necessary to change the condition of unit weight of that substance without changing its temperature.

Can you give any illustration of this?

SPECIFIC HEAT.

Experiment 106. — Select two deep tin cans of the same shape and size. Put about 8 ounces of water into one can, and the same weight of fine shot into the other. Allow them to stand until they have the same temperature, that of the room. Set the two cans at the same instant into a pan of hot water. Keep the contents of each can well stirred, and, at the end of one minute, take the temperature of each.

Which is hotter?

The same amount of heat was added to each, but the temperatures are different. It is evident that it requires more heat to raise the temperature of water than it does to produce an equal increase of temperature in an equal weight of lead. We express this fact by saying that the *specific heat* of lead is less than that of water.

Find out which is more easily heated, iron or water.
Which has the higher specific heat?

QUESTIONS FOR THOUGHT AND READING.

1. Why is water sometimes put into a cellar when there is fear that the vegetables may freeze?

2. It is sometimes difficult, when on a high mountain, to heat water sufficiently for cooking potatoes. Why?

3. Suppose a large area of the Rocky Mountain region has a "low barometer" to-day. What kind of weather are they

probably having there, and what kind of weather will they probably soon have in the Eastern States? Study the weather maps for the answer to this question.

4. Why do clothes dry faster on a windy day than on a calm one?

5. If bodies expand when heated, why does mud crack when exposed to the heat of the sun?

6. When a carriage is not well oiled, the wheels sometimes "set." Why?

7. Why, in summer, is it more likely to be cloudy in the afternoon than in the morning?

8. Why is a place situated near a large body of water likely to have a more moderate winter than an inland region a little further south?

9. How do Fahrenheit and Centigrade thermometers differ?

10. Why will hot tea dissolve more sugar than iced tea?

11. Why are iron tires heated before they are put upon wagon wheels?

12. What conditions determine the amount of rain that a given place may have?

CHAPTER V.

RADIANT ENERGY.

1. NATURE OF RADIATION.

A NEW KIND OF MOTION.

Experiment 107. — Sit before an open fire; the face becomes very warm. Hold a sheet of paper between the fire and the face; the feeling of warmth is removed *immediately*. Take away the paper; the feeling of warmth reappears *immediately*.

Did this quick change take place because the air between the paper and the face was heated and cooled instantaneously?

Was this air thus heated and cooled?

Are you sure that *something* passed from the fire to your face? Why?

Did that something go in a straight or in a crooked line?

How do you know?

Do you think that it was air that passed from the fire to your face, a kind of wind? Why?

Do you think that it was a motion in the air, like sound?

Experiment 108. — Hold the side of your face in bright sunshine; it feels warm. Hold a newspaper between the

sun and your face. The paper cuts off something that came from the sun to your face.

Did the something that passed from the sun to your face move in a straight line? How do you know?
Was it air? Why?
Was it a motion in the air? Why?
Does the air reach to the sun?

Hold the newspaper in front of your face, and look toward the sun. It cuts off whatever warmed the face.

Can you see the sun through the paper?
Does the paper also cut off the light that comes *directly* from the sun?

Instead of the paper, hold a pane of glass between your face and the sun.

Does the glass cut off whatever warmed the face?
Does the glass cut off light?
Do you think that whatever comes from the sun to warm the face is much like light? Why?

The sun is intensely hot; in other words, its molecules are in very active vibration. These vibrations of hot molecules produce waves in a medium called the *ether*, just as the vibrations of a sounding tuning-fork produce waves in the air. These waves travel through the ether with the very great velocity of about 186,000 miles a second. When they fall upon ordinary bodies, they *warm* them; when they fall upon the eye, they produce the effect that we call *vision* or seeing. The difference in the sensations of warmth and vision produced by the ether-waves does not depend upon any difference in the

waves, but upon the differences of the bodies upon which the waves fall.

The propagation of ether-waves through space is called radiation. The energy carried by ether-waves is called radiant energy.

The path of an ether-wave is called a *ray*.

A collection of parallel rays constitutes a *beam*.

The ether occupies the mighty spaces between the earth and the heavenly bodies, and the minute spaces between the molecules of ordinary matter. Planets and molecules alike are imbedded in the ether. We may consider the heating effects or the luminous effects of radiant energy.

When we consider the heating effects, the radiant energy is sometimes called *radiant heat*.

When we consider the luminous effects, the radiant energy is called *light*.

Some of the ether-waves are so long, and others are so short, that they cannot produce vision even when they enter the eye.

---

2. LIGHT.

The part of radiant energy that can excite vision constitutes light.

HOW WE SEE BODIES.

Experiment 109. — Take an unlighted candle or lamp into a darkened room.

Can you see the candle?
Can you see the table?

Light the candle.

Can you see the candle-flame?
Can you see the table?

We see objects only when they send light to the eye.

Think of different ways of illustrating this fact. Bodies that are seen by their own light are *self-luminous*, as a candle-flame or a "live" coal.

Bodies that are seen by the light they have received from another body are *illuminated*, as a table or a "dead" coal.

Which of the following are self-luminous and which are illuminated: the moon; the planets; the stars?

RECTILINEAR PROPAGATION.

Experiment 110. — Make a pin-hole in each of three cards. So place the cards that the flame of a candle may

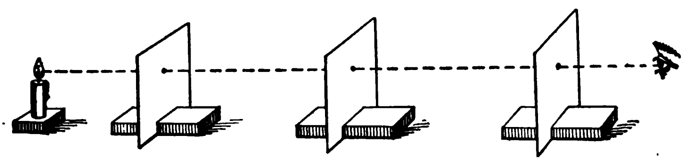

FIG. 82.

be seen through the three pin-holes at once. Carefully pass a thread through the pin-holes and stretch it.

In what kind of a line were the three holes when you saw the candle-flame through them?

Light travels in .... lines.

Under ordinary conditions this is true, but light may be made to travel along any path desired.

Experiment 111. — In a cardboard, cut a circular hole about the size of a nickel coin. Hold the cardboard in front of a small candle-flame, and receive the radiant energy that passes through the opening upon a white

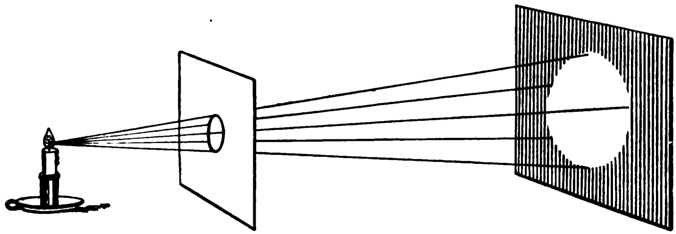

FIG. 83.

screen held parallel to the cardboard. Move the screen backward and forward, noticing the shape and the variations in the size of the lighted area upon the screen.

How does this experiment show that light travels in straight lines?

SHADOWS.

Experiment 112. — Hold an opaque body, as a croquet ball, between a lamp-flame and a white paper screen, and

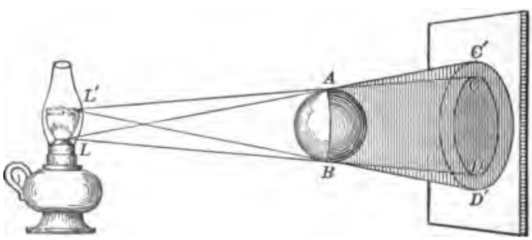

FIG. 84.

about two inches from the screen. Turn the flat side of the flame, not its edge, toward the screen.

Why is there a shadow?

The shadow is the darkened space from which the ball cuts off light.

It is not merely the dark circle on the screen.

Move the ball further from the screen.

Describe the change thus caused in the shadow.

The central part of the shadow, *i.e.* the complete shadow, is called the *umbra*. The surrounding partial shadow is called the *penumbra*.

Experiment 113. — Prick a pin-hole through that part of the screen that is in the umbra. Look through this pin-hole toward the lamp.

How much of the flame can you see?

What part of the flame sends light to any point in the umbra?

Prick a pin-hole through that part of the screen that is in the penumbra. Look through this pin-hole toward the lamp.

How much of the flame can you now see?

Why is the penumbra less dark than the umbra?

If you were to look toward the lamp through a hole pricked in the paper just outside the penumbra, how much of the flame could you see?

Experiment 114. — Coat the lower half of a lamp chimney with asphaltum varnish. At the height of the flame,

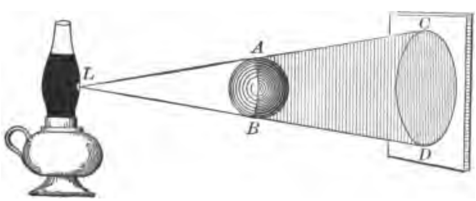

FIG. 85.

scrape the varnish from a spot about $\frac{1}{8}$ of an inch in diameter. Using this lamp, repeat Experiment 112.

Describe the penumbra.

Why are the shadows cast by an arc electric lamp so "clear cut"?

The extent of the penumbra depends upon the area of the source of light.

THE MOON'S PHASES.

Experiment 115. — Chalk half the surface of a croquet ball, and blacken the other half. Chalk on the floor the circumference of a circle at least 10 feet in diameter. Let some one walk around the circle holding the croquet ball with the chalked side continually turned in the same direction, as toward the east. Standing at the center of the circle, turn around so as directly to face the ball as it is carried around you. Notice the changes in the shape of the visible part of the chalked surface at different points of the circuit.

Make a sketch of the chalked surface as it appears at each of the four cardinal points, east, north, west, and south.

How do these forms compare with the four phases of the moon?

Consider that the chalked surface of the ball represents the half of the moon's surface that is illuminated by the sun.

Explain the changing appearance of the moon as it moves around the earth once in four weeks.

ECLIPSES.

In Fig. 86, *S* represents the sun; *E*, the earth; and *M*, the moon in different positions with reference to the sun and the earth.

In which position of the moon do we have an eclipse of the sun?

In which position of the moon do we have an eclipse of the moon?

In what part of the earth's shadow must the moon be that there may be a total eclipse of the moon?

In what part of the earth's shadow must the moon be that there may be a partial eclipse of the moon?

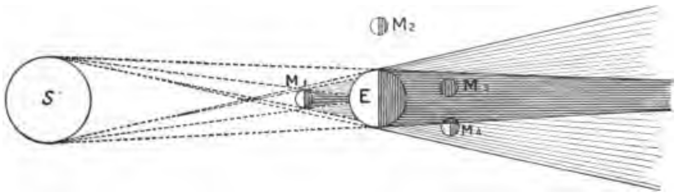

FIG. 86.

Can there be an eclipse of the moon at the time of half moon?

In what part of the moon's shadow must a person be to observe a total eclipse of the sun? Indicate one such position in the figure.

In what part of the moon's shadow must a person be to observe a partial eclipse of the sun? Indicate two such positions in the figure.

---

3. REFLECTION.

Experiment 116.— Let sunlight fall upon a hand mirror, and throw the light so that it will form a bright spot on the ceiling. We say that the light is *reflected* by the mirror.

Experiment 117.— Place a very hot brick upon an inverted flower-pot. About two feet away, place a delicate

thermometer (an air thermometer is desirable; see Exp. 91) the bulb of which has been coated with soot or lamp-black. Between the two, place a screen of glass. Notice that the hot brick has very little or no effect on the thermometer. Hold a sheet of tin plate as shown in the figure so that the energy that passes obliquely upward from the brick is thrown obliquely downward and upon the blackened bulb of the thermometer. The thermometer shows that its bulb is heated.

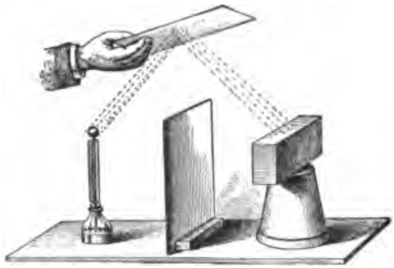

FIG. 87.

Some of the energy radiated by the brick is *reflected* by the tin plate.

The turning back of ether-waves into the medium from which they came is called the reflection of radiant energy.

Do you detect any difference between the energy radiated by the sun and reflected by the mirror, and the energy radiated by the brick and reflected by the tin plate?

Can the ether-waves reflected by the mirror produce vision?

Can the ether-waves reflected by the tin plate produce vision?

These two sets of ether-waves differ only in the matter of *wave-length.* The waves that we call light are shorter and follow in quicker succession than the others.

Can short ether-waves pass easily through glass?

Can long ether-waves pass easily through glass?

If they are absorbed by the glass, will they warm the glass ?

If the waves pass easily through glass, will they warm the glass ?

The radiant energy that falls upon a body must be transmitted, or absorbed, or reflected by that body.

What word describes a substance that freely transmits light ?

What word describes a substance that does not transmit light ?

Give three illustrations of substances of each class.

What kind of surfaces make the best reflectors ?

Experiment 118. — Repeat Experiment 116, using a piece of window glass instead of a hand mirror.

Does glass transmit all of the light that falls upon it ? How do you know ?

What is the real reflecting substance of a hand mirror, glass or metal ?

Experiment 119. — Hold the hand mirror horizontal, and a little below the level of your eye. Hold a lead pencil in a vertical position, and with its point resting upon the middle of the mirror. Look carefully, and you will see two images of the pencil point.

Account for this.

LAW OF REFLECTION.

Experiment 120. — Fasten a narrow piece of looking-glass to the vertical face of a rectangular wooden block, and place it on a piece of paper lying on the table. Stick a hat-pin upright in the paper at *F*, about a foot from the

mirror, and hold the eye in such a position that the image of the pin, *f*, can be clearly seen. In the line of vision, set two pins, one at the lower edge of the mirror, at *B*, and

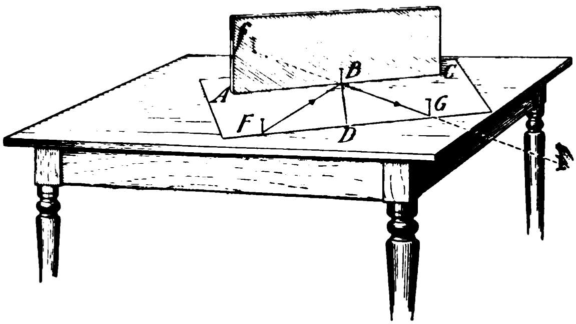

FIG. 88.

the other at *G*, near the edge of the paper. Run the pencil point along the lower edge of the mirror, tracing the line, *AC*, on the paper. Draw the lines, *FB* and *BG*. From *B*, draw *BD* perpendicular to *AC*.

FB represents the *incident* ray.
BG represents the *reflected* ray.
FBD represents the *angle of incidence.*
GBD represents the *angle of reflection.*

Compare these two angles.

The angle of incidence and the angle of reflection are ----------.

Experiment 121. — Using the necessary apparatus, show how one may "see around a corner."

An object seems to be in the direction from which the light enters the eye.

4. REFRACTION.

BY A PLATE.

Experiment 122. — Fill with water a clear glass bottle that has flat sides, and cork it. Place the bottle upon a red-ink line drawn upon a sheet of paper. The line should project beyond the bottom of the bottle, as shown in the figure. Look obliquely downward through the bottle at the line. The rays that pass from *B* to the eye are bent as they pass from the bottle to the air at *c*; the part of the line that is under the bottle is apparently displaced. Instead of appearing at its true position, it appears in the direction of *Ec*, the direction from which the light enters the eye, and *B* seems to be at *b*. If you have a thick paper-weight of clear glass, use it as you did the bottle of water. This bending of the ray is called *refraction*.

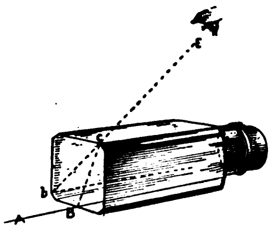

FIG. 89.

What other cases of refraction by water have you seen? What instances of refraction by glass have you seen?

When light passes obliquely from one medium to another, it generally suffers a change of direction, and is said to be refracted.

BY A PRISM.

A *prism* is a transparent body with two refracting plane surfaces that are not parallel.

THE SPECTRUM.

Experiment 123. — Let a beam of sunlight fall upon a glass prism, and receive the light, after it has emerged,

upon a screen of white paper or cloth, as shown in the figure. The effect may be heightened by darkening the room.

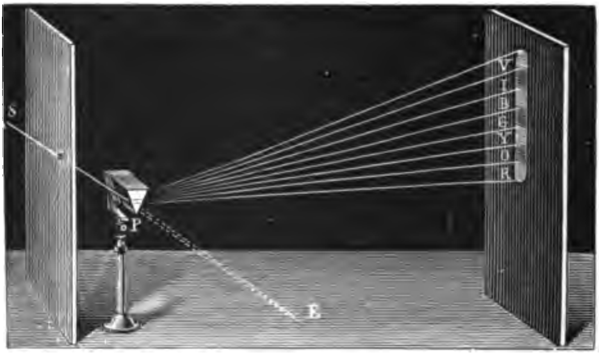

FIG. 90.

Has the light been refracted?

Which of the rays constituting the beam have been refracted the most? Which the least?

How many colors do you see upon the screen?

Call the colored band thus formed a *solar spectrum.*

The separation of the blended rays of light in this way is called the dispersion of light.

What color is produced by the rays that are refracted the most?

What color is produced by the rays that are refracted the least?

The ether-waves that produce the effects of different color differ only in wave-length.

The ether-waves that produce violet color are the shortest and are, therefore, refracted the most.

The ether-waves that produce red color are the longest and are, therefore, refracted the least.

There are, in a beam of sunlight, rays of shorter wave-length than those of the violet. They cannot produce vision and, therefore, are not light. They are called *ultra-violet* rays. They may be detected by a photographic plate.

There are, in a beam of sunlight, rays of greater wave-length than those of the red. They cannot produce vision and, therefore, are not light. They are called *ultra-red* or "obscure heat" rays. They may be detected by a thermometer.

What is the color of sunlight?

How do the colors of the spectrum compare with those of the rainbow?

What is the refracting substance that gives rise to a rainbow?

BY A LENS.

A *lens* is a transparent body with two refracting surfaces, one or both of which are curved.

Where have you ever seen a lens?

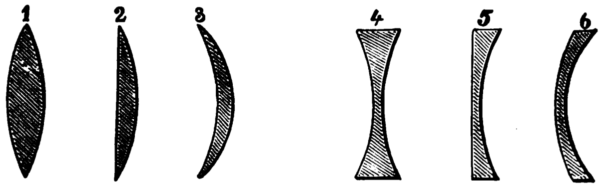

FIG. 91.

Experiment 124.—Hold a pocket lens or a reading-glass in the sun's rays, and in such a position as to produce the brightest possible spot upon a sheet of paper.

Why is this spot so bright?

The point at which the refracted rays converge is called the *focus* of the lens.

Hold your hand at the focus of the lens.

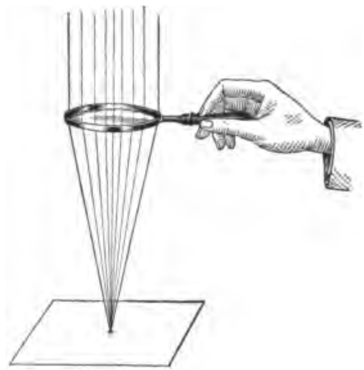

Fig. 92.

What effect do you notice?

Blacken a spot on the paper with lead pencil or soot, and hold the spot at the focus. Try thus to ignite the paper.

Explain the heating effect of such a lens thus used.

Look through the lens at this page.

Do you notice any change in the apparent size of the letters?

Such a lens thus used produces a ___________ effect.

Can you explain this effect of the lens?

Examine the lens and find out whether it is thicker at the edges or at the center.

Are all lenses like this in this respect?

A lens that is thickest at the center is a *converging* lens.

A lens that is thickest at the edges is a *diverging* lens.

To which of these classes does a reading-glass belong?
A magnifying-glass?
The large object-lenses of an opera-glass?
The small eye-lenses of an opera-glass?
Are spectacle lenses converging or diverging? Examine as many as you can.

QUESTIONS FOR THOUGHT AND READING.

1. How fast does light travel?

2. From what source does the moon receive its light?

3. State the relative position of the sun, moon, and earth at the time of each of the following phenomena: a new moon; a full moon; the first quarter.

4. How do you account for the row of images that you see when an object is placed between two parallel mirrors?

5. How do you account for the arrangement of images that you see when an object is placed between two mirrors making an acute angle with each other?

6. Why is clear water deeper than it looks to be? (Think of the light as coming obliquely from the bottom of the pond to the eye.)

7. To what is the color of a piece of red glass due? Is the same true for any transparent body? Give illustrations.

8. What are complementary colors?

9. What is the most common optical apparatus that you can mention?

10. Describe a magic lantern, and show how it is used to produce magnified pictures.

11. Can a diverging lens be used as a "burning-glass"?

CHAPTER VI.

MAGNETISM AND ELECTRICITY.

1. MAGNETISM.

Break the tangs from two or three flat, worn-out files. Smooth the ends and sides of the files on a grindstone. Procure three or four stout knitting-needles. Have the files and needles magnetized in some way. Any good-natured dynamo tender at an electric-light station, or at the power-house of an electric railway will do it for you. The needles may be magnetized by stroking them lengthwise with one end of a strong magnet, rubbing always in the same direction.

A PECULIAR ATTRACTION.

Experiment 125. — Bring one end of one of the magne-

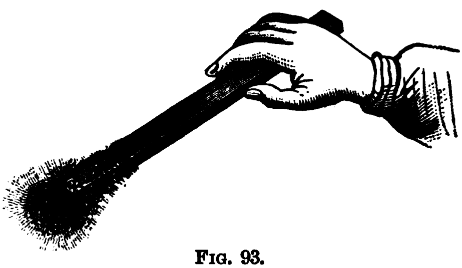

Fig. 93.

tized bars or needles near small bits of iron, as carpet-tacks.

What effect do you notice?

See if you can produce a like effect upon brass tacks or pins.

Determine the effect upon the small pieces of a broken sewing-needle.

The force that thus attracts iron and steel is called *magnetism*.

Experiment 126. — Float one of the magnetized files upon water, as shown in the figure. Place each of the other files in a stout paper stirrup, and support the stirrup by a thread two or three feet long. See that the files are at a considerable distance from each other, and that each hangs level. Thrust each of the knitting-needles through two corners of a triangular piece of paper, to the third corner of which the end of a horsehair or of a silk fiber has been fastened by wax. Suspend the needles as you did the files.

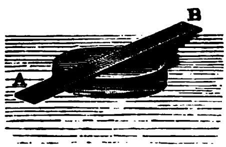

FIG. 94.

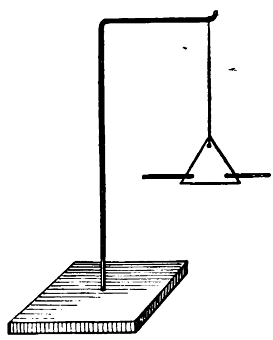

FIG. 95.

How many of the suspended files point east and west?

How many of the suspended files point north and south?

How many of the suspended needles point east and west?

How many of the suspended needles point north and south?

A body that attracts iron and steel and that, when freely suspended, points north and south (or nearly so) is called a magnet.

If the magnet is straight, it is called a *bar magnet.*

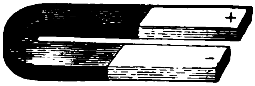

FIG. 96.

If the magnet has a U-shape, as shown in Fig. 96, it is called a *horseshoe magnet.*

MAGNETIC POLES.

Experiment 127.—Roll a bar magnet in iron-filings. Lift the magnet from the filings.

FIG. 97.

At what parts of the magnet is the attraction greatest?
At what part of the magnet is the attraction least?

The ends of a magnet are called the poles of the magnet.

HOW TO MAKE A MAGNET.

Experiment 128. — Dip your knife-blade into iron-filings.

Is it a magnet?

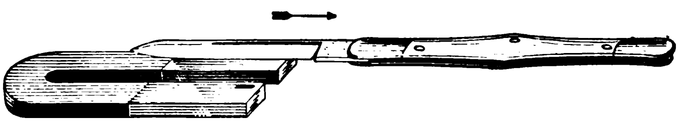

FIG. 98.

Draw the knife-blade several times across the pole of a good magnet and always in the same direction, as from the handle to the point. Again dip it into iron-filings.

Is the knife-blade now a magnet?

We say that the knife-blade has been *magnetized.*

Can you use this knife-blade to magnetize another knife-blade? Try to do so.

Another way of making a magnet will be given in the section on current electricity.

Try to magnetize a horse-shoe nail (soft iron).
Try to magnetize a steel pen.
Which substance makes the better magnet?
Can you magnetize a body made of a metal other than steel?
Try to do so.

MAGNETIC NEEDLES.

Experiment 129. — Suspend one of the magnetized needles as shown in Figure 95.

In what direction does it point?

Turn it from that position and release it.

Does it return to its former position?

A bar magnet so suspended as to let it take its chosen position relative to the earth is called a magnetic needle.

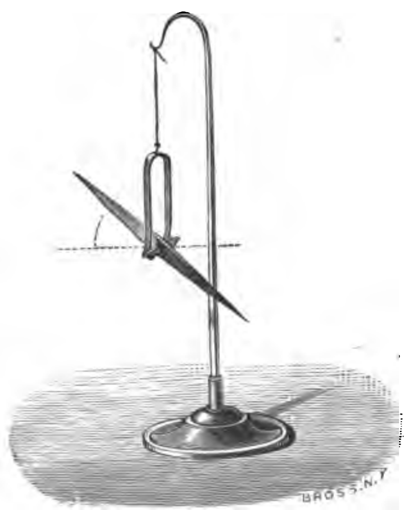

FIG. 99.

Tie a fine thread around the north end of the needle, or in some other way mark it so that it may be distinguished from the other end. Similarly mark all of the magnets

used in Experiment 126. Call the marked end of each magnet the *north-seeking pole*, and the other end the *south-seeking pole.*

A magnetic needle suspended so that its ends may move up and down instead of horizontally is called a *dipping-needle.* (Fig. 99.) A sewing-needle suspended at its center of gravity by a fine thread or hair and then magnetized makes a good dipping-needle.

FIG. 100.

Experiment 130. — Balance one of the file magnets on the end of an egg, and let it go. What position does it assume? Watch it carefully, and do not let it fall.

Is such a balanced magnet a magnetic needle?

LAW OF MAGNETIC POLES.

Experiment 131. — Place one of the magnetic needles at a considerable distance from the others. Bring one end of another magnet held in the hand near one end of the suspended magnet.

Do the two magnet poles show attraction or repulsion?

Are the two magnet poles of the same kind or of opposite kinds?

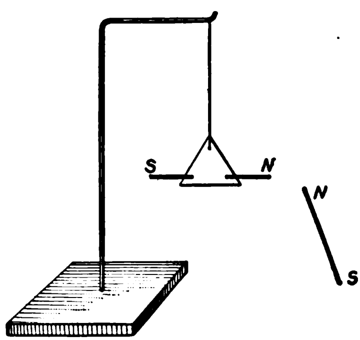

FIG. 101.

Bring each end of the

magnet in your hand near each end of the magnetic needle, and see if it is true that,

N repels N,	N attracts S,
S repels S,	S attracts N.

Like magnetic poles ---------- each other; unlike magnetic poles ---------- each other.

EFFECT OF BREAKING A MAGNET.

Experiment 132. — Break one of the magnetized needles, and roll each half in iron filings.

How many poles has each half?

Break each of the halves into two quarters, and roll each quarter in iron filings.

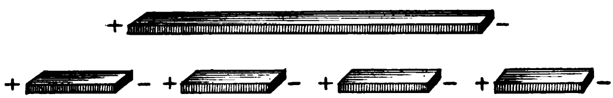

Fig. 102.

How many poles has each quarter?

Is each quarter of the needle a complete magnet?

How far do you think this division could be carried with like results?

It is probable that every molecule has its poles, or is polarized, and that, could one be isolated, it would be a perfect magnet.

Can you imagine that when a body is magnetized its molecules are turned until all of their like poles extend in the same direction?

What would such a body probably be?

THE EARTH A MAGNET.

Experiment 133. —Suspend a small dipping-needle over the middle of a bar magnet lying on the table.

Does the needle hang level or not?

Move the needle toward one pole of the magnet.

Does the needle now hang level?

If it does not, notice which end of the needle *dips* downward.

Move the needle toward the other end of the magnet.

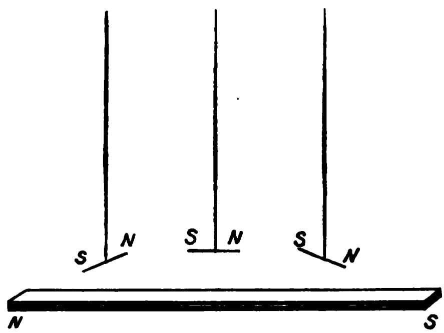

FIG. 103.

Does the needle now hang level?

Does the same end of the needle dip downward as before?

How do you explain these movements?

Call the part of the bar magnet that is midway between its poles, the *equator* of the magnet.

If we should carry a dipping-needle from the south pole of the earth across its equator, and to its north pole, we should observe similar movements of the needle.

North of the equator, one pole of the dipping-needle is depressed; south of the equator, the other end of the needle is depressed.

At any place on the earth, the angle that the dipping-needle makes with a horizontal line is called the *dip* or *inclination* of the needle at that place.

The dip corresponds somewhat closely to the latitude of the place.

What is the dip of the needle at the magnetic equator of the earth?

What is the dip of the needle at the magnetic poles of the earth?

The magnetic poles of the earth vary a little from the geographical poles of the earth.

Owing to the fact that the magnetic poles of the earth do not coincide with its geographical poles, the magnetic needle, at some places, does not point exactly to the geographical north. The angle that the axis of a magnetic needle makes with the geographical meridian at any place is called the *declination* or the *variation* of the needle at that place.

Give two or more reasons for thinking that the earth is a magnet.

QUESTIONS FOR THOUGHT AND READING.

1. What is a "lodestone"?

2. Devise a simple experiment to show that magnetic force acts through glass.

3. Where is the north magnetic pole?

4. If your knife-blade is a magnet, how can you tell which is the north-seeking pole?

5. How can you destroy the magnetism of a steel magnet?

6. What is induced magnetism, and how could you illustrate it?

7. Try to pick up one magnet by another by bringing the end of one in contact with the end of the other. Explain the results.

2. STATIC OR FRICTIONAL ELECTRICITY.

We do not know just what electricity is. We do know, however, that it is the common cause of a great variety of interesting phenomena.

ELECTRICAL ATTRACTION.

Experiment 134. — Draw a silk ribbon about an inch wide and a foot long between two layers of warm flannel, and with considerable friction. Hold the ribbon near the wall.

Do you notice any unusual attraction?

Experiment 135. — Place a sheet of paper on a warm board, and briskly rub it with india-rubber. Hold it near the wall, as you did the ribbon.

Do you notice any unusual attraction?

NOTE. — The apparatus used for experiments with static electricity should be warm and dry, and free from dust.

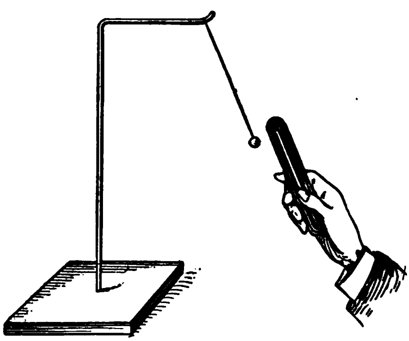

FIG. 104.

Experiment 136. — From the pith of elder or of sunflower, whittle three or four balls about $\frac{3}{8}$ of an inch in diameter, and roll them round between the palms of the hand. Coat one of these with gold-leaf or aluminium-leaf, and suspend it from any convenient support by

a fine silk thread. Briskly rub a stout stick of sealing-wax with warm flannel, and bring the wax near the pith-ball.

Do you notice any unusual attraction ?

Call the suspended pith-ball an *electroscope.* Repeat the experiment, using a glass rod that has been rubbed with silk.

Repeat the experiment, using a rubber comb that has been rubbed with flannel.

We say that the sealing-wax, the glass rod, and the comb have been *electrified.*

How were these bodies electrified ?

Experiment 137. — Balance a yardstick upon the end of an egg supported upon a glass bottle. Bring an electrified body near one end of the stick, but do not let them come into contact.

FIG. 105.

What effect do you notice ?

An electrified body .... an unelectrified body.

The state or condition of a body that has the power of attracting other bodies, as here illustrated, is called *electrification.* Electrification that is developed in this way is called *static* or *frictional.*

Try to find some other substance that you can electrify in this way.

ELECTRICAL REPULSION.

Experiment 138. — Repeat Experiment 136, and allow the pith-ball to touch the sealing-wax.

What happens to the pith-ball?

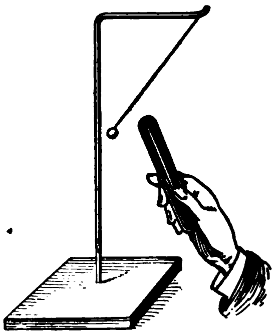

FIG. 106.

Touch the pith-ball with the hand. Bring the electrified glass rod near the ball.

Do you notice an attraction or a repulsion?

Allow the ball to touch the rod.

Do you now notice an attraction or a repulsion?

Make the same tests with the electrified rubber comb. In each case, the pith-ball was electrified by contact with the electrified body. We say that it was electrified by *conduction*.

An electrified body may repel another electrified body.

KINDS OF ELECTRIFICATION.

Experiment 139. — Electrify the pith-ball by contact with the rubbed sealing-wax.

Is the electrified ball attracted or repelled by the electrified wax?

Is the electrified ball attracted or repelled by the flannel with which the wax was rubbed?

Touch the ball with the hand, and repeat the experiment, using the glass rod and the silk.

May electrification be manifested by repulsion as well as by attraction?

Is there more than one kind of electrification?

How does the electrification of the sealing-wax compare with that of the flannel with which it was rubbed?

Call the electrification of the glass rod, produced by rubbing it with silk, positive.

Call the electrification of the sealing-wax, produced by rubbing it with flannel, negative.

The electrification of any body is either positive or negative.

The electrification of the rubbed body is different from that of the body with which it was rubbed.

LAWS OF ELECTRICAL ATTRACTION AND REPULSION.

Experiment 140. — Electrify a glass rod, and suspend it in a paper loop or a wire stirrup supported by a silk thread. Electrify another glass rod, and bring it near the first.

What happens?

Electrify the sealing-wax, and bring it near the suspended glass rod.

What happens?

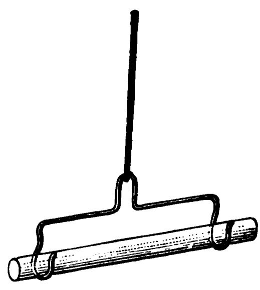

FIG. 107.

Electrify the sealing-wax, and suspend it in the paper loop. Electrify another stick of sealing-wax, and bring it near the first.

What happens?

Electrify the glass rod, and bring it near the suspended sealing-wax.

What happens ?

Bodies similarly electrified .... each other ; bodies oppositely electrified .... each other.

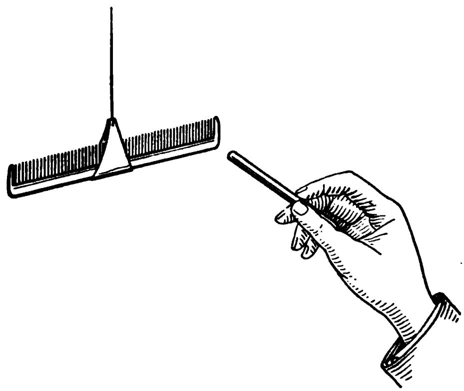

FIG. 108.

Electrify the rubber comb, and bring it near the suspended sealing-wax.

What happens ?
Is the electrification of the comb positive or negative ?

ELECTROSCOPES.

Experiment 141. — By means of fine silk threads about 4 inches long, suspend three pith-balls side by side. The supporting wire may be bent and carried by a wooden base, as shown in Fig. 95, or thrust into the cork of a bottle. Bring the balls into contact with an electrified body, as the glass rod, *i.e.* electrify them alike by con-

duction. Notice their action toward each other. Also notice the effect of the electrified rod upon them.

Explain what you notice.

Is the electrification of the rod negative or positive?

Is the electrification of the balls negative or positive?

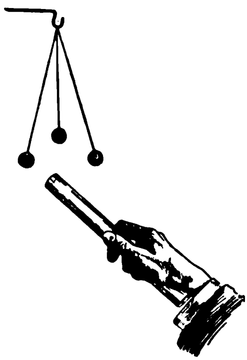

FIG. 109.

Bring, in succession, other electrified bodies near the pith-balls while they are repelling each other. From the effect upon the balls, determine the kind of electrification of each such body. In several experiments, we have used the pith-balls to detect the presence and to determine the kind of electrification. Apparatus used for such a purpose is called an *electroscope.*

Experiment 142. — Make a more delicate electroscope as follows: Solder one end of a wire to the center of a metal disk about 2 inches in diameter. Pass the wire through a rubber stopper that fits a bottle 4 or 5 inches in diameter. Bend the lower end of the wire so as to form a stirrup, as shown in the figure. Bend a strip of tin-foil, an inch long and a quarter of an inch wide, across its middle and place it in the stirrup. To each end of the tin-foil, paste a strip of very thin metal leaf (as gold-leaf)

FIG. 110.

a quarter of an inch wide, and an inch and a half long. Place the cork, etc., in position. We may call this apparatus a *metal-leaf electroscope.* Bring an electrified body near the disk of this electroscope, and notice the prompt divergence of the leaves.

USE OF THE ELECTROSCOPE.

Experiment 143. — Bring an electrified body, as the rubbed glass rod, near the metal-leaf electroscope. While the leaves are divergent, touch the disk with a finger. Remove first the finger, and then the rod.

Describe the movements of the leaves. You will understand them better in a little while.

Bring a positively electrified body near the disk.

What effect has the positive electrification upon the leaves ?

Any body that produces such an effect upon the leaves is positively electrified.

Bring a negatively electrified body near the disk.

What effect has the negative electrification upon the leaves ?

Any body that produces such an effect upon the leaves is negatively electrified.

CONDUCTORS AND INSULATORS.

Experiment 144. — Support a yardstick upon a glass tumbler. Bring an electrified glass rod to one end of the stick, and hold some small pieces of gold-leaf or of paper a little distance under the other end of the stick.

The gold-leaf or paper will be attracted and repelled by the stick. The electrification passed along the stick from end to end.

Experiment 145. — Fasten a metal weight to each end of a fine wire about 4 feet long. Place one of the weights upon the disk of the metal-leaf electroscope and the other upon a bottle as far away as the length of the wire will allow. Bring an electrified body to the weight on the bottle, and notice the effect upon the leaves of the electroscope.

What do you observe?
How do you account for it?

Substitute a dry silk thread for the wire, and repeat the experiment.

What effect is now produced?

Wet the thread, and repeat the experiment.

What effect is now produced? Explain.

Substances that easily permit the transference of electrification along them are said to be good conductors. Very poor conductors are called insulators or non-conductors.

A conductor supported by a non-conductor is said to be *insulated.*

Why was the tumbler used in Experiment 144?
Why was the bottle used in this experiment?
Is dry silk a conductor or an insulator?
What other substances have you seen used for insulators?

INDUCTION.

Experiment 146.— Bring an electrified body, as a rubbed glass rod, near the disk of the metal-leaf electroscope;

notice the divergence of the leaves. Remove the electrified body; notice the collapse of the leaves.

Does the collapse of the leaves show there was any transfer of electrification from the rod to the electroscope?

Experiment 147.— Moisten a yardstick, and support it with one end on the disk of the metal-leaf electroscope, and the other end on a glass bottle. Hold an electrified body, of known electrification, as the rubbed glass rod, near the end of the stick that rests on the bottle, but not in contact with it.

Are the leaves electrified? How do you know?

Has any electrification passed from the rod to the electroscope?

When an electrified body is thus brought into the vicinity of an unelectrified conductor, opposite electrifications appear in the different parts of the latter.

What kind of electrification is attracted by the positive electrification of the glass rod?

To what part of the yardstick will that kind of electrification be attracted?

What kind of electrification is repelled by the positive electrification of the glass rod?

To what part of the yardstick will that kind of electrification be repelled?

A body in which opposite electrifications are thus manifested is sometimes said to be *polarized*.

What influence produces and maintains this separation of electrifications in a polarized body?

Place a finger upon the polarized yardstick.

Can the positive electrification of the glass rod draw the negative of the yardstick any nearer to itself than it did before?

Can it repel the positive electrification of the yardstick any further from itself than it did before?

Will it do so?

Do you think that the positive electrification of the yardstick will escape through your person to the earth?

If it does so escape, in what electrical condition will it leave the yardstick?

Remove your finger from the yardstick.

Can the positive electrification that was repelled through you to the earth now return to the yardstick?

Remove the electrified rod.

Is there now anything to hold the negative electrification at the end of the yardstick that is over the bottle?

What then will become of that electrification?

This way of electrifying a body by the influence of an electrified body and without contact with it is called *electrification by induction.*

Is the electrification thus induced of the same kind as the electrification that induced it, or of the opposite kind?

Do you now understand how the electroscope was electrified in Experiment 143?

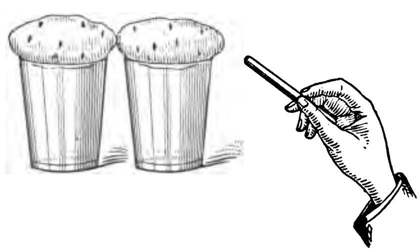

FIG. 111.

Experiment 148. — Set two smooth potatoes, end to end and touching each other, upon two tumblers. Electrically, the two potatoes form one insulated conductor. Bring an electrified body, as a stick of sealing-wax, near one end of one of the potatoes.

What one word describes the electrical condition of the insulated conductor?

Holding the sealing-wax in position, separate the tumblers.

Describe the electrical condition of each potato.

Verify your answer by tests with the metal-leaf electroscope.

Repeat the experiment, using a rubbed glass rod instead of the sealing-wax.

How do the results now obtained compare with those previously obtained?

Experiment 149. — Place the insulated potatoes 3 or 4 feet apart, and connect them by a light wire. The

FIG. 112.

ends of the wire may be bent half an inch from each end, and the short arms thrust into the potatoes. Bring an electrified body near one of the potatoes.

Of what three parts does this single insulated conductor consist?

Describe the electrical condition of each part.

While the electrified body is held near the potato, remove the wire, using a rubber comb or a piece of glass tubing for that purpose.

Why should a non-conductor be used for removing the wire?

Determine the kind of electrification on each potato.

Account for what you find.

THE ELECTROPHORUS.

Experiment 150. — Melt together about 3 parts of rosin, 1 of beeswax, and 1 of shellac. Nearly fill a round tin plate with the mixture, being careful to avoid the formation of bubbles on the surface. Allow the plate to stand until the mixture hardens. From a quarter-inch board, cut a disk about 2 inches less in diameter than that of the plate. Carefully round and smooth the edge of the disk, and securely fasten an insulating handle at its center. This handle may be a stout rod or tube of glass or rubber, a small bottle, or a piece of sealing-wax. Cover the disk with smooth tin-foil pasted evenly upon it. Whip the resin plate with flannel or catskin.

Is the resin plate thus electrified?

How can you prove that your answer is correct?

Place the disk upon the resin plate. Study the accompanying figure. Remember that the resin plate is a non-

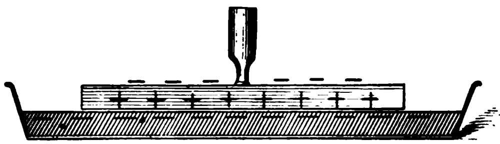

FIG. 113.

conductor, and that the disk touches it at comparatively few points. Practically, the disk is separated from the resin plate by a thin layer of air.

What one word describes the electrical condition of the disk?

How was that condition produced?

Touch the disk with the finger.

What electrical change do you suppose just occurred in the disk?

Explain that change.

What kind of electrification now remains upon the disk?

An insulated body that has only one kind of electrification is said to be *charged* with electricity.

Place a few bits of thin paper upon the disk, and lift it from the resin plate.

Do you notice any peculiar action of the paper bits?

If so, explain that action.

Touch the edge of the charged disk to the ear.

Do you hear anything?

If so, explain the sound.

The disk may be charged and discharged many times without again electrifying the resin plate.

Is the disk charged by conduction or by induction?

When a body is charged by conduction, how does the kind of its electrification compare with that of the charging body?

When a body is charged by induction, how does the kind of its electrification compare with that of the charging body?

THE LEYDEN JAR.

Experiment 151. — Smoothly paste tin-foil upon the inner and the outer surfaces of a thin glass tumbler, covering them to about two-thirds of their height. Cut a circular piece of pasteboard to fit into the top of the

tumbler. Coat a wooden ball about half or three-quarters of an inch in diameter with tin-foil, and into it insert one end of a stout copper wire. Pass the free end of the wire through a perforation at the center of the pasteboard. Bend the lower part of the wire to form a foot upon which the wire may stand resting on the inner coating of the tumbler, as shown in the figure. This apparatus is a *Leyden jar.*

FIG. 114.

Charge the disk of the electrophorus. Hold the Leyden jar in one hand, and bring the edge of the electrophorus disk near enough to the knob of the jar to produce a spark.

Does the inner coat of the jar receive electrification from the disk of the electrophorus?

Is the charge thus communicated positive or negative?

Give the jar a dozen such charges in succession. Hold the jar by its outer coat, and touch the knob with a finger of the other hand.

Do you feel a slight "shock"?

Does it hurt you?

A "shock" that is painful to one may be pleasant to another. If the shock was not disagreeable, give the jar two dozen successive charges from the electrophorus, and discharge it as before.

Are you sure that you feel the shock?

If you do not feel it, you may conclude that the tumbler you used was ill-fitted for use as a Leyden jar, and that it should be replaced by another.

Has the charge on the inner coat of the jar any inductive effect on the outer coat?

What is that effect?

Why were you told to hold the outer coat in the hand while you were charging the jar?

Are the charges of the inner and of the outer coats of the same kind?

Does the charge of the outer coat attract or repel the charge of the inner coat?

Can you imagine that the charge of the outer coat held or "bound" the charge of the inner coat, and thus made it easier to add the second and subsequent charges from the electrophorus?

Can you imagine the charge of the jar to become so great that the attraction between the opposite charges on the two coats would become so intense as to pierce the glass that separated them and thus to rush together?

Many Leyden jars have actually been ruined in just that way.

Note.—With the electrical apparatus that you now have, you may perform many interesting and entertaining experiments at home. Try to "think out" some such experiments, and see if they will "work."

QUESTIONS FOR THOUGHT AND READING.

1. How can you show the kind of electricity in a body by means of the metal-leaf electroscope?

2. Why can you not electrify a conductor as well as a nonconductor when held in the hand?

3. Why is it impossible to give a Leyden jar a strong charge when it rests upon a piece of glass during the process of charging?

4. Explain the use of lightning rods. How may they become elements of danger rather than of safety?

5. Why is a pith-ball first attracted to an electrified body, and then repelled from it?

6. A pair of conductors separated by a non-conductor is called an electrical condenser. Where have you seen such a condenser?

7. To what piece of apparatus described in this book can you compare earth, air, and cloud in a thunder-storm?

8. Does static electricity exist in the body of a charged conductor, or simply on its outer surface?

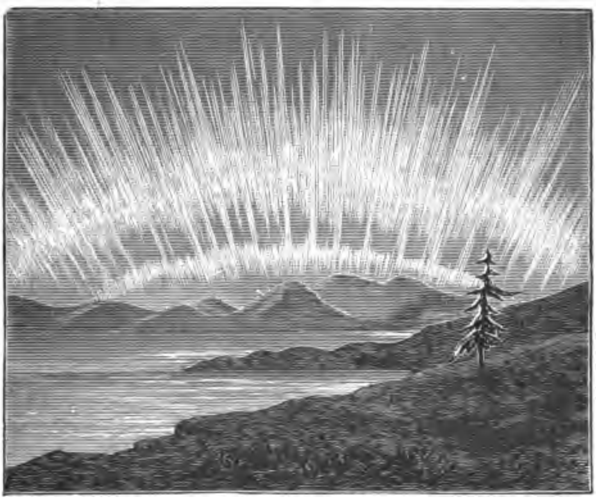

FIG. 115.

9. What phenomenon is represented in Fig. 115, and where may it be observed? Have you any idea as to its cause?

10. Did you ever see an "electrical machine" for the development of large quantities of static electricity? If so, tell all that you can about it.

3. CURRENT OR VOLTAIC ELECTRICITY.

A VOLTAIC CELL.

Experiment 152. — Wind one end of a bright copper wire, about a yard long, around a bright metal cartridge-shell (No. 10 or 12 of an ordinary fowling-piece), and twist it tightly to make a good contact. Bend the middle of a narrow strip of clean sheet zinc across a wooden stick, and support the zinc inside the shell, as shown in the

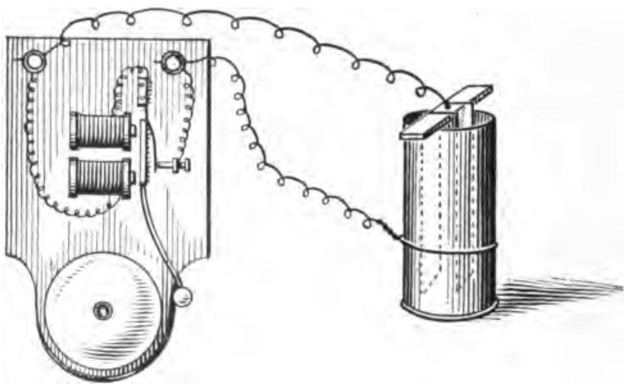

Fig. 116.

figure. The zinc strip should hang without touching the shell at any point. Fasten one end of another copper wire about a yard long to the middle of the zinc strip. Connect the free ends of the two wires to the binding posts of an electric bell. Prepare a dilution of sulphuric acid by slowly pouring 1 part of acid into 10 parts of water, and, with the diluted acid, nearly fill the cartridge-shell.

What happens to the bell?

Examine the contents of the shell.

Do you see anything that looks like a vigorous chemical action between the acid and the zinc?

The shell, acid, and zinc constitute a *voltaic cell.*

The cell gives a *current* of electricity.

The energy of this current rings the bell.

Empty the liquid from the cell, and put water in its place.

Do you notice any evidence of chemical action in the cell?

Does the cell now give a current that rings the bell?

Voltaic electricity is produced by .... action.

A series of several voltaic cells constitutes a *voltaic battery.*

Experiment 153. — Make a simple voltaic battery as follows: Cut two strips of sheet zinc and four of copper, each $3\frac{3}{4}$ inches long and $1\frac{3}{4}$ inches wide. Bend a square shoulder upon each of these metal plates half an inch from the end, and punch a hole at the middle of each shoulder, as shown in Fig. 117. Amalgamate the zinc plates by dipping them into the dilute sulphuric acid used in Experiment 152, and rubbing a few drops of mercury upon their wet surfaces until they are bright and glistening. Cut a strip of wood 10 inches long, 3 inches wide, and half an inch thick. With an inch screw that is clean and bright passing through the hole in the shoulder, fasten a zinc plate $1\frac{1}{2}$ inches from each end of the board, and parallel with the end of the board. In similar manner, fasten a copper plate on each

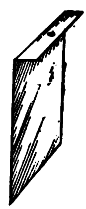

FIG. 117.

side of each zinc plate and three-quarters of an inch from it, as shown in Fig. 118. See that the plates are parallel to each other; set the screws tight, so that their points will project through the board as far as possible. No

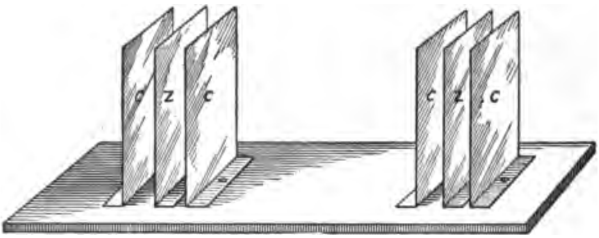

FIG. 118.

plate must touch any of the other plates. Place the plates thus arranged in two tumblers, as shown in Fig. 119. With copper wires, connect the tips of the two screws that carry the copper plates in one tumbler with

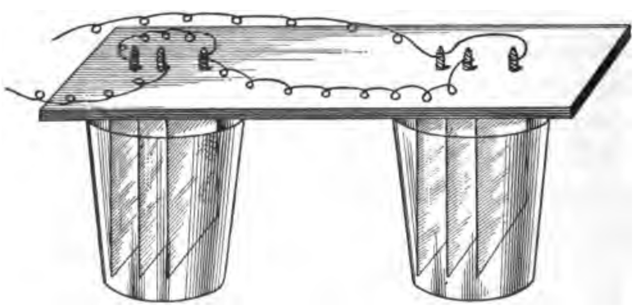

FIG. 119.

the tip of the screw that carries the zinc plate in the other tumbler. Connect a second wire to the other two copper plates, and a third wire to the remaining zinc plate. Such a battery may consist of any number of

cells thus joined, the copper plates of one being joined to the zinc plate of the next.

Prepare a battery solution as follows: Put 2 quarts of water into a gallon earthenware jar, and slowly pour into it half a pint of sulphuric acid. Carefully stir the two liquids together, and add 8 ounces of powdered bichromate of potassium. Handle this solution carefully, or it will stain your fingers and burn your clothes. When the solution is cool, nearly fill the tumblers with it and place the metal plates in the liquid.

The free ends of the wires are the *electrodes* of the battery. The free end of the wire that runs to the copper strips is the *positive electrode*, and the copper strips are the *negative plates*. The free end of the wire that runs to the zinc strip is the *negative electrode*, and the zinc strips are the *positive plates*. When the electrodes are brought together, a current flows through the plates, liquids, and wires, and we say that the *circuit is closed*.

When any of these parts are disconnected, the current ceases to flow, and we say that the *circuit is broken* or open.

When the battery is not in use, the plates should be kept out of the liquid. It is well to provide two empty tumblers to support them, and to catch the drippings from them.

ELECTROMAGNETS.

Experiment 154. — Wind 3 or 4 feet of insulated No. 18 copper wire upon a piece of soft iron; a large wire nail will answer. Dip the nail into iron-filings, and see if it has any magnetic power. Join the bare ends of this wire to the

electrodes of a voltaic battery that is in working order. Again dip the nail into iron-filings.

What effect do you notice?
What do you suppose to be the cause of this effect?

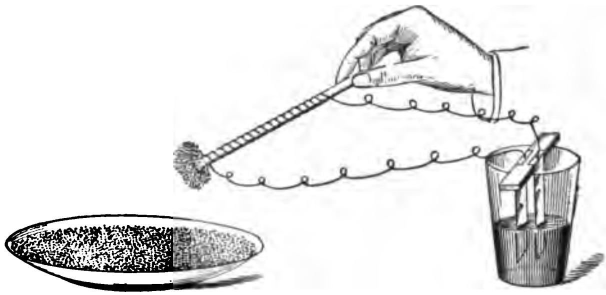

Fig. 120.

Break the circuit of the battery.

What effect do you notice?

An electric current flowing around a piece of soft iron magnetizes it.

A magnet thus formed is called an *electromagnet.*

Is an electromagnet a permanent or a temporary magnet?
Can you show how this principle is used in the electric telegraph?

Experiment 155. — Hold the two wires from a battery, with open circuit, over a magnetic needle, as shown in the figure.

What is the effect upon the needle?

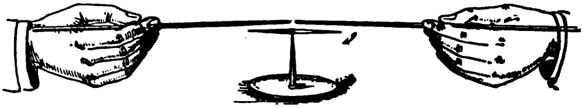

Fig. 121.

Bring the two ends of the wire together, and thus close the circuit.

What is the effect upon the needle?

NOTE.—If there is no easily perceptible effect on the needle, the battery is not in good working order. In such a case, observe the directions given at the end of Experiment 158.

A current of electricity deflects a magnetic needle.

HEATING EFFECTS.

Experiment 156.—Connect the two electrodes of the battery used in Experiment 153 by a very fine iron wire, such as the florist uses in tying up flowers. The length of the iron wire between the ends of the copper wires should be about half an inch. Lower the plates of the battery into the solution.

Name two effects of the electric current upon the iron wire.
How is the light of an incandescence lamp produced?
Of what material is the filament of such a lamp made?
How is it kept from burning up?

If you can get a two-candle power incandescence lamp, put it into the circuit of your battery, and send the current through it.

An electric current flowing through a poor conductor, like the fine iron wire, has part of its energy converted into heat.

BLASTING.

Experiment 157.—Again put the short, fine iron wire into the circuit, and imbed it in half a teaspoonful of

gunpowder. See that no more powder is near by. Lower the plates into the liquid.

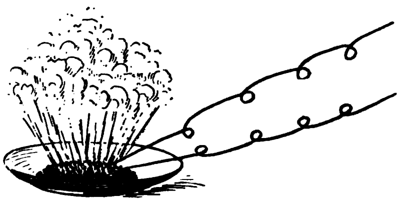

FIG. 122.

What effect do you notice?

What practical applications of the electric current are illustrated by this experiment?

ARC LAMPS.

Experiment 158. — Sharpen two electric-light carbons, and make them the electrodes of the battery. Lay the

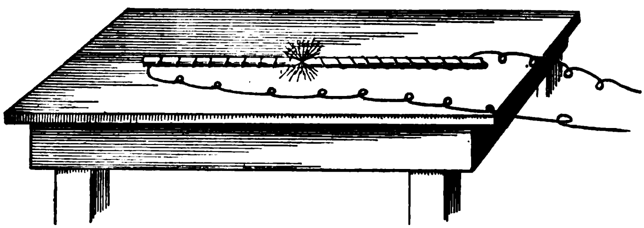

FIG. 123.

carbons on the table, and close the circuit by bringing their points together.

Describe what you see at the point of contact of the carbons.

What does this experiment illustrate in a feeble way?

If the experiment does not "work," examine your electric-light "plant." See that the zinc plates are well amalgamated, be sure that all metal connections are bright and firm, and use a fresh supply of the battery solution.

ELECTROLYSIS.

Experiment 159. — Change the connections of the battery plates so that one of the leading wires joins the two screws that carry the zinc plates, and so that the other leading wire joins the four screws that carry the copper plates. Fasten a bright iron screw to the free end of the wire from the zinc plates, and a piece of copper to the free end of the wire from the copper plates, and suspend them in a solution of copper sulphate (blue vitriol), as shown in the figure. After the current has been flowing for a few minutes, remove the screw from the solution, and examine its surface.

FIG. 124.

What do you find on the screw?

Where did it come from?

Can you think of any way of making the current remove the deposit it placed upon the screw? If so, try it.

An electric current that passes through a solution of a chemical salt may decompose it. The process is called electrolysis.

What practical applications of current electricity are illustrated by this experiment?

How could we have plated the screw with silver?

Summarize the effects of the electric current.

QUESTIONS FOR THOUGHT AND READING.

1. Refer to Fig. 116 and explain the action of an electric bell.

2. Show, by a drawing, how a push-button operates in the ringing of an electric bell.

3. Only one wire is necessary in telegraphy. How is the return current possible?

4. How is the current that operates the electric telegraph generally produced?

5. Make a simple drawing to illustrate the operation of the electric telegraph.

6. Why does the carbon filament of an incandescence lamp become luminous as the current passes through it, and why does it not burn up?

7. Explain the process of electro-plating.

8. What is a galvanometer, and what is the principle upon which it is constructed?

9. What is meant by an induced current, and how may one be produced?

10. What is a dynamo? Describe one as well as you can.

CHAPTER VII.

THE COMPOSITION OF THE ATMOSPHERE.

The chief constituents of our atmosphere are carbon dioxide, watery vapor, oxygen, and nitrogen.

CARBON DIOXIDE.

This gas is often called carbonic acid gas. Its chemical symbol is CO_2, which indicates that each molecule of the gas is composed of 1 atom of carbon and 2 atoms of oxygen.

Experiment 160. — Mount a candle on a J-shaped wire as you did in Experiment 3. Light the candle and lower it into a large, wide-mouthed jar. A two-quart glass fruit-jar will answer well.

Does the candle burn in the air in the jar?
How long will it continue to burn?

This process of burning is called *combustion*.

Do you think that anything other than air is now in the jar?
Why?

Fill the jar with water, and empty out the water.

What is in the jar now?

Put a handful of small lumps of marble into the jar, cover the lumps with water, and add small quantities of

hydrochloric (muriatic) acid as may be needed to keep up a vigorous chemical action for a while.

The gas that is thus formed is *carbon dioxide.*

Lower the lighted candle slowly into the jar.

Will the candle burn at the mouth of the jar?

Will air support combustion?

Will the candle burn at the bottom of the jar?

What property of carbon dioxide do you infer from this fact?

Determine by the candle if the gas fills the jar at once. Allow the chemical action to stop. Let the jar stand uncovered for five minutes, then lower the lighted candle again into the jar.

Is the flame extinguished or not?

What other property of carbon dioxide does this illustrate?

Experiment 161. — Fasten a tuft of cotton batting to the end of a wire or a glass rod, dip it into alcohol, ignite it, and quickly thrust the large flame into the jar of carbon dioxide.

What is the effect upon the flame?

If your house was burning and you could deluge it with carbon dioxide, would that put out the fire as well as water would?

Which would do the greater injury to carpets, curtains, etc., in such a case, water or carbon dioxide?

Experiment 162. — Lower a small tumbler (or a wide-mouthed bottle) into the jar, as you would a bucket into a well; draw up a tumblerful of the gas. See if the

candle will burn in it. Draw up another tumblerful; carefully carry it ten feet or more, and then see if the candle will burn in it. Draw up another tumblerful, and pour it, as if it was water, upon the flame of a candle burning at the bottom of another tumbler.

FIG. 125.

Which is heavier, air or carbon dioxide? How do you know?

FIG. 126.

Experiment 163. — Pour a little more hydrochloric acid into the jar until chemical action is again vigorous. Place one end of a yard of rubber tubing in the jar, and suck the air from the other end. When you taste the carbon dioxide (it will not harm you), lower the outer end of the tube, and hold a tumbler beneath it. Pour the contents of the tumbler upon a candle-flame, as you did in Experiment 162.

FIG. 127.

Did you siphon the gas from the jar?

What does that fact prove about the density of carbon dioxide as compared with that of air?

Has the gas an "acid" taste?

In what respects is carbon dioxide like water?

Experiment 164. — Pour a little lime-water into a bottle. Cork the bottle and shake it.

Do you notice any change in the color of the lime-water?

Empty the bottle and rinse it. Fill the bottle with carbon dioxide dipped or siphoned from the jar. Pour a little lime-water into the bottle. Cork the bottle and shake it.

What change do you notice in the color of the lime-water?

The milky condition of the liquid is due to the formation of calcium carbonate (chalk or limestone) by the chemical union of carbon dioxide and lime-water. This is the most common "test" for the presence of carbon dioxide.

Write a summary of the properties of carbon dioxide.

Although carbon dioxide forms only a small percentage of our atmosphere, it is a very important constituent of it, as will appear more clearly in a little while.

Can you devise a method of detecting the presence of carbon dioxide in the atmosphere of the schoolroom?

This gas is not poisonous, but it may kill by suffocation, just as water may.

Why is it a wise precaution to lower a lighted taper before descending to the bottom of an unused well or mine?

Plants feed upon the carbon dioxide of the atmosphere.

WATERY VAPOR.

Recall Experiments 95 and 102.

What reasons have you for thinking that there is moisture in the atmosphere?

Where does this moisture come from?

Is the amount of it in the atmosphere always the same?

Under what conditions may this moisture become visible?

What is it then called?

OXYGEN.

Experiment 165. — Hold the angle of the bent glass tube that you used in Experiment 55 in the flame of the alcohol lamp and, when it is red-hot, bend it to an angle of about 60 degrees. Pass one end of this bent tube through a cork that snugly fits a stout test-tube (the kind

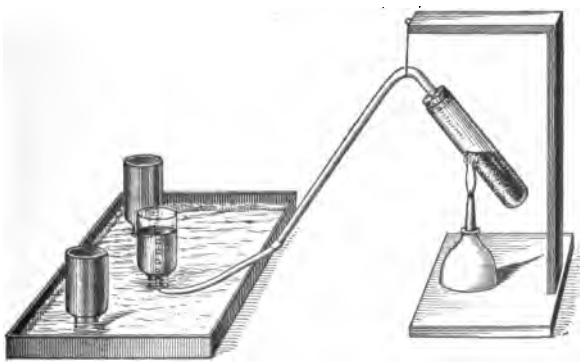

FIG. 128.

known as an ignition-tube is best). Attach a piece of rubber tubing about a foot in length to the other end of the glass tube. Mix equal weights of manganese dioxide (black oxide of manganese) and of clean potassium chlorate (chlorate of potash). Put about 2 thimblefuls of this mixture into the ignition-tube, insert the cork tightly, and support the tube in a slanting position, as shown in the figure. Fill with water, three wide-mouthed half-pint bottles of clear glass, and invert them over water, as you

did in Experiment 2, being careful that the water in the pan is not more than $\frac{3}{4}$ of an inch deep. Hold the free end of the delivery-tube under the water, and heat the mixture in the ignition-tube with the alcohol flame. The upper part of the mixture should be heated first, and the heat so regulated that the gas shall come off steadily. The first bubbles that appear are air; and should be allowed to escape. Then carry the end of the delivery-tube to the mouth of a bottle. In this way, fill the three bottles with pure oxygen. Remove the end of the delivery-tube from the water-pan before you remove the lamp. Slide a piece of thick paper under the mouth of one of the bottles. Remove the bottle from the water-pan, keeping its mouth closed with the wet paper.

Compare the appearance of oxygen with that of air.

Light a wooden splinter, blow out the flame, and quickly plunge the glowing spark into the oxygen.

Describe the effect.
How can you distinguish oxygen from air?

Remove the splinter, blow out the flame, and repeat until the gas in the bottle fails to rekindle the splinter.

Do you think that there is much oxygen in the bottle now? Why?
What do you think is in the bottle?

Pour a little lime-water into the bottle and shake it.

What do you now think is in the bottle?
How do you suppose it got there?

Experiment 166. — Make a small loop at the end of a copper wire. Bend the wire at a right angle near the loop.

Place a small piece of brimstone in the loop. Remove another bottle of oxygen from the water-pan. Ignite the brimstone (sulphur), and quickly plunge it into the small bottle of oxygen.

Describe the effects.

Cover the bottle with a wet card. The gas formed by the burning of the sulphur is irritating when inhaled. Smell of it cautiously.

Do you recognize the gas now in the bottle?

It is called *sulphurous oxide*, and its chemical symbol is SO_2.

What does this symbol tell you about the composition of each molecule of the gas?

Experiment 167. — Fray out the end of a piece of fine-wire picture-cord, and dip it into melted brimstone, so as to form a little sulphur bead at the end of the wire. Remove the other bottle from the water-pan, and see that there is half an inch of water in the bottom. Ignite the sulphur, and quickly thrust it into the oxygen.

FIG. 129.

Describe the effect of the gas upon the iron wire thus heated by the burning sulphur.

When oxygen unites with another element, as just illustrated, it forms an *oxide*, and we say that the other substance was *oxidized*.

Can you find the iron oxide in the bottle?
What oxides have you formed in these experiments?

If the oxidation is very slow, we call the process ***rusting*** or *decay*.

If the oxidation is rapid, we call the process ***burning*** or ***combustion.***

Combustion generally is accompanied by the production of heat and light.

The characteristic property of oxygen is that it aids ....

Name some of the uses of oxygen.

Describe some startling thing that would happen if the atmosphere was wholly oxygen.

Summarize the properties of oxygen.

If you have time and disposition, you may prepare more oxygen, and perform the following experiments at home:

Experiment 168. — Fill a quart bottle with oxygen, and take it into a darkened room. Dip into melted brimstone one end of a fine, steel watch spring that you have partly straightened by heating it in a lamp flame. Ignite the sulphur bead, and quickly lower it into the jar of oxygen.

Fig. 130.

Experiment 169. — Wind one end of a piece of copper wire around a piece of charcoal to form a handle for it. In a dark room, ignite the charcoal at the alcohol lamp and quickly plunge it into oxygen.

Describe the effect.

When the charcoal no longer burns, pour a little lime-water into the bottle and shake it.

What do you detect in the bottle?
What is its chemical symbol?
Where did it come from?

Experiment 170. — Place a lighted candle on a stand between two boys, *A* and *B*. Let *B* fill his mouth with oxygen drawn through a tube. *A* may blow out the flame, leaving a glowing wick; *B* may then puff oxygen upon the wick and relight it. Repeat the experiment until the mouthful of oxygen is exhausted. *B* need not inhale the oxygen, but if a little does get into his lungs it will do no harm.

NITROGEN.

Experiment 171. — Bend the wire that carries the candle used in Experiment 3 so that its short arm shall be 5 or 6 inches long. Light the candle, and over it invert the bottle used in Experiment 163. Push the mouth of the bottle 4 or 5 inches below the surface of lime-water contained in a larger vessel, as shown in the figure. Notice how far the water rises in the bottle.

FIG. 131.

What element of the air unites with the burning candle?

The candle contains a considerable proportion of carbon.

Name one oxide that is forming in the bottle.

What is approximately measured by the quantity of water that has entered the bottle since the beginning of the experiment?

Remove the candle and slip a piece of thick paper under the mouth of the bottle. Lift the bottle from the water and shake it. Set it down right-side up.

What effect do you notice?

Why was lime-water instead of water used in this experiment?

The gas now left in the bottle is nearly all *nitrogen*. Lower a lighted candle into the nitrogen.

What effect do you notice? Explain this. See Experiment 160.

We say that nitrogen is a *non-supporter of combustion*. This is its chief property.

What other gas that is a non-supporter of combustion can you name?

Examine the gas as to color, transparency, etc., and summarize the properties of nitrogen.

How do these properties of nitrogen compare with those of oxygen?

What do you think is the chief use of nitrogen as a part of the atmosphere?

Air is composed chiefly of oxygen and nitrogen. About one-fifth of its volume is oxygen, and nearly four-fifths of its volume is nitrogen.

Air is a mixture, and not a chemical compound; the oxygen remains oxygen, and the nitrogen remains nitrogen.

Is air an oxide of nitrogen?

If you have the time and disposition, you may perform the following experiment at home: —

Experiment 172. — Fill a bell-glass, or other convenient vessel, with oxygen, and a stoppered bell-glass of the same size with nitrogen. Cover their mouths with glass plates, and bring them mouth to mouth, as shown in Fig. 132. Remove the stopper and the glass plates, and introduce a lighted taper having a long wick. As the taper passes through the nitrogen, the flame is extinguished; if the wick is still glowing, it will be rekindled in the oxygen. By moving the taper up and down from one gas to the other, it may be rekindled repeatedly.

FIG. 132.

PRODUCTS OF COMBUSTION AND RESPIRATION.

Experiment 173. — Lower a burning candle into a clear, dry, narrow-necked flask. Notice the formation on the inner surface of the flask.

What is it?

Remove the candle. Pour some lime-water into the flask, and shake it.

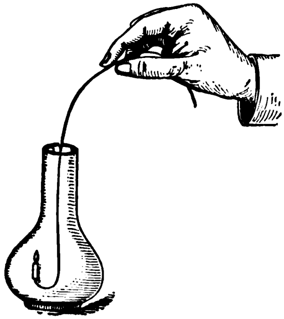

FIG. 133.

Do you notice any change in the lime-water?
If so, account for it.
Name two products of the combustion of the candle.

Experiment 174.— Breathe upon a piece of cool, dry glass.

What forms on the glass?
Account for it.

Experiment 175.— Fill the lungs with air. Slowly breathe through a tube so that air from your lungs shall bubble up through clear lime-water.

Fig. 134.

Account for the change in the lime-water.

Name two products of respiration.

How do these two products of respiration compare with the two products of combustion?

What process do you, therefore, infer is going on within the tissues of your body?

How can you account for the heat of your body?

Why should a schoolroom be well ventilated?

In the ventilation of a living-room, why should allowance be made for lamps and gas jets?

QUESTIONS FOR THOUGHT AND READING.

1. About how much oxygen and how much nitrogen would you expect to find in 200 cubic feet of air?

2. What is the most striking property of oxygen, and what of nitrogen?

3. How can you distinguish carbon dioxide from nitrogen?

4. Name some possible sources of the carbon dioxide in our atmosphere.

5. What do the following terms mean: oxidation; decay; rust; combustion?

6. Why are canned fruits put up hot, and kept in air-tight jars?

7. What reasons can you give for thinking that rapid oxidation is taking place within the tissues of your body?

8. What changes take place in the air that is breathed in, and breathed out?

9. In a room heated by a furnace, where does the air come from? Is it supposed to be pure or impure? A flue should be provided for its exit. Why? Should it open near the ceiling or the floor of the room? Why?

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